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Human capital, wealth, and nutrition in the Bolivian Amazon

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Abstract

We analyze anthropometric variables of a society of forager-horticulturalists in the Bolivian Amazon (Tsimane′) in 2001–2002. Community variables (e.g., inequality, social capital) explain little of the variance in anthropometric indices of nutritional status, but individual-level variables (schooling, wealth) are positively correlated with nutritional status. Dietary quality (foods high in animal proteins), access to foraging technology, and traditional knowledge of medicinal plants are related to better anthropometric indices.

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1. Introduction

In contemporary industrialized nations and in many developing nations, anthropometric indices of nutritional status (e.g., physical stature) correlate reliably with a wide range of indicators of individual well being, such as income, life expectancy, health, and labor

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productivity (Steckel and Rose, 2002; Fogel, 1994; Komlos, 1989; Steckel, 1995, 2003; Strauss and Thomas, 1998). Historical evidence suggests that during the early stages of industrialization, anthropometric indices deteriorated despite income growth. Historical case studies from Japan, Britain, Austria, Hungary, Ireland, and the United States suggest that during the early stages of industrialization adults from rural areas had higher physical stature than their urban counterparts (Baten, 2000; Komlos, 1987, 1989, 2003; Mokyr and Grada, 1994; Shay, 1994). Komlos calls the downswings in physical stature during the early stages of industrialization "one of the most amazing findings" of historical anthropometric studies, and attributes it to growing income inequality, increase in the relative price of food and animal proteins, losses of food during farm-to-city transport, population growth, to unsanitary conditions in cities, as well as to commercialization that brought about a substantial changes in relative prices (Komlos, 1994).

We study a contemporary small-scale, pre-industrial society of foragers and horticulturalists in the Bolivian Amazon, the Tsimane′, to identify the covariates of nutritional status among adults (18 years of age and older) during the early stages of sustained participation in a market economy. The results can complement earlier findings obtained on rural self-sufficient populations in a historical setting. Why did self-sufficient peasants and farmers during the initial stages of industrialization in the 18th and 19th centuries enjoyed better nutritional status than their urban counterparts despite having lower income as first suggested in Komlos (1985)? Studies in early-industrial societies suggest that nutritional status improved as the distance from the village to the city increased, presumably because distance shielded people from the unsanitary conditions of cities and because the countryside had greater availability of food and lower prices for staples (Komlos, 1995; Shay, 1994).

Studies in economic history as well as in social epidemiology from industrialized nations suggest that income inequality harms health (Kawachi, 2000; Komlos, 1994; Wilkinson, 1996) partly because it creates psychosocial stress (Wilkinson, 1997), erodes social capital (Kawachi and Kennedy, 2002), and makes it harder to agree on the provision of public goods (Deaton, 2003; Putnam et al., 1993). Estimating the effect of income inequality and social capital on health in contemporary industrial societies is hard because confounding variables such as government transfers, immigration, and racial and ethnic heterogeneity come into play. Estimating the effects of income inequality and social capital in 18th and 19th-century industrial societies is even harder owing to the shortage of information, particularly information related to social capital. Contemporary pre-industrial, small-scale societies provide an alternative setting to explore the relations of interest since they lack most of these confounding variables.

Yet, unlike in industrialized nations, in small-scale, contemporary pre-industrial societies income inequality might have a modest effect on health because there is likely to be little income inequality owing to social norms of sharing and redistribution (Godoy, 2001; Gurven et al., 2000; Kaplan and Hill, 1985), and because the same social norms should protect individual health from the presumably harmful effects of income inequality.

More importantly, the Tsimane′ allow one to test whether standard determinants of nutritional status in industrialized nations, such as income, wealth, and human capital hold in societies with different institutional arrangements. To illustrate: if the relation between nutritional status and income, wealth, or human capital displays standard diminishing marginal utility, then one should expect individual resources to have strong protective effects on own nutritional status among poor people such as one finds in contemporary pre-industrial, small-scale societies. Yet, when social norms of sharing, gift giving, and reciprocity cause individual resources to leak to the rest of the community, then social norms will attenuate the protective effect of individual resources on own health.

Our goal is to estimate the correlation between anthropometric indicators of adult nutritional status and village variables, such as income inequality, social capital, and village-to-town distance. We expect social capital to protect the nutritional status of individual adults, and we expect income inequality to have a negligible effect on own nutritional status. Moreover, we want to estimate the effect of income on adult nutritional status and, in so doing, assess whether pervasive norms of reciprocity and gift giving dilute the protective effects of household resources on own nutritional status.

2. The setting and the people

The Tsimane′ is a Foraging and Horticultural Amerindian Society in the Department of Beni, in the Bolivian Amazon. For the regression analysis, we draw on a panel composed of two annual surveys done in 2001 and 2002, but we also make occasional reference to a five-quarter panel study in two villages (1999–2000) with 60 households and 325 subjects, and to a survey with 509 households in 58 villages done in the year 2000. Detailed ethnographic background on the Tsimane′ can be found elsewhere (Byron, 2003; Chicchón, 1992; Daillant, 1994; Ellis, 1996; Foster et al., in press; Huanca, 2000; Reyes-García et al., 2003a; Reyes-García, 2001; Vadez et al., in press). For definitions and summary statistics of the variables see Table 1.

Adult nutritional status among Tsimane′ is low relative to standards of industrial nations. The information in Table 1 suggests that age and sex-standardized z-scores of sum of triceps and sub-scapular skinfold (ZSUMSK2), mid-arm muscle area (ZMAM), and height for age (ZHT) were 0.72, 0.82, and 1.79 S.D. below US norms. Despite poor indices of nutritional status, Tsimane′ display variance in nutritional status. The coefficients of variation (S.D./mean) for age and sex-standardized physical stature (ZHT), skinfolds (ZSUMSK2), and mid-arm muscle area (ZMAM) were 0.39, 0.67, and 0.95. BMI for men (mean = 23.30; S.D. = 2.31) and women (mean = 22.87; S.D. = 2.76) were similar ($p < 0.17$), but men were taller (mean = 163.59 cm, S.D. = 4.95) and heavier (mean = 62.44 kg, S.D. = 7.50) than women (mean physical stature = 150.53 cm, S.D. = 4.35; mean weight = 51.88, S.D. = 7.01).

The Tsimane′ are poor and essentially autarkic. Mean annual personal per capita income from cash earnings and from the imputed value of farm and forest goods consumed was US$ 332, a third of the average income in Bolivia (US$ 980/person), one of the poorest nations in Latin America (Godoy et al., 2002). Goods bought in the market accounted for only 3% of the total value of household consumption.

As most lowland indigenous Amazonian peoples, the Tsimane′ practice slash-and-burn agriculture. They clear plots from the forest each year to plant crops such as plantains, rice, maize, and cassava for subsistence and for sale. The forest area cleared for agriculture can be used as a proxy for annual income or consumption because most of a household's annual

Table 1
Definition and summary statistics of variables used, Tsimane′ subjects over 18 years of age, 2001 and 2002

Variable	Definition	*N*	Mean	S.D.
Dependent				
ZSUMSK2	Age and sex-standardized *z*-score of sum of triceps and sub-scapular skinfolds (ZSUMSK2) and mid-arm muscle area (ZMAM)(Frisancho, 1990)	559	−0.72	0.48
ZMAM		557	−0.82	0.78
BMI	Body-mass index (kg/m^2) for both sexes; in regression, entered in logs	554	23.17	2.46
Physical stature (ZHT)	Sex and age-standardized *z*-score of height (Frisancho, 1990)	557	−1.79	0.71
Explanatory				
Household and personal-level				
log income	Area/person deforested in 2000 in tareas; 10 tareas = 1 hectare. Includes old-growth and fallow forest; in regression in logs Used as proxy of income	557	1.97	2.35
Social capital (Soc Cap)	Village generosity last week excluding subject's household. Generosity = total times last week house (a) gave gifts of chicha, cooked food, maize, rice, fish, meat, manioc, seeds, medicines or (b) aided others hunt, fish, farm, cure, buy, or do other work	557	13.92	8.17
Physical stature (ZHT)	Sex and age-standardized *z*-score of height (Frisancho, 1990). Only when using BMI, ZMAM, and ZSUMSK2 as explanatory variables	557	−1.79	0.71
Male	Sex of subject: 1 = male; 0 = female	560	0.69	0.46
Age	Age of subject in years	560	34.35	12.58
Human capital	Modern human capital; principal component analysis of: schooling, reading, writing, and speaking Spanish ability, and math skill. Varimax rotation	552	−0.0002	1.00
log wealth	Value in Bolivianos of wealth/person based on 8 traditional and 10 modern physical assets; in regression entered in logs; 1 US$ = 6.31 bolivianos	557	440	392
Household size	# people in the house at time of the survey	560	6.03	2.61
Explanatory				
Village-year level				
Travel time (travel)	Hours walking from village to town or to nearest road in dry season (only year 1)	37	13.36	12.51
Population	# of households in village	72	17.90	9.97
Gini	Village Gini of area/person deforested	72	0.35	0.11
Nurses	# modern health-care workers in village	71	0.30	0.88
Healers	# traditional healers in village	71	1.36	1.69

food consumption and cash earnings come from the forest area they clear each year for subsistence and for commercial agriculture (Vadez et al., in press). During 2000 and 2001, Tsimane′ households ($n = 557$) cleared an average of 0.10 hectares of fallow forest/person (S.D. = 0.13) and 0.08 hectares of old-growth forest/person (S.D. = 0.17), or a total of 0.19 hectares for both types of forests/person (S.D. = 0.23). Only 10 households or 1.79% of the sample reported clearing no forest.

Wealth was divided almost evenly between modern and traditional physical assets. Traditional assets include domesticated animals and artifacts that form part of their traditional culture (e.g., bows, dug-out canoes). Modern assets include metal tools and implements, and such luxury items as radios. The value/person of total assets of 440 bolivianos/person (US$ 70/person) was divided almost evenly between modern and traditional ones.

Tsimane′ have among the lowest indices of modern human-capital of any Amazonian population in Bolivia. Only 60% of their villages have primary schools, compared with 80% for other Amazonian populations in Bolivia (Secretaría Nacional de Asuntos Etnicos, 1994). About 30% of Tsimane′ children 6–10 years of age attend school; among the neighboring Mojeño and Yuracaré Amerindians the share is twice as high (Secretaría Nacional de Asuntos Etnicos, 1994). The average adult in our sample had completed only 1.5 years of school (S.D. = 2.19). Sixty-five percent of adult women and 46% of adult men had no schooling at all. Thirty-four percent of the sample could not speak Spanish, and 43% spoke it poorly. Sixty-eight percent of the sample could not read Spanish, 62% had no math skills, and 65% could not write in Spanish. Women scored below men in all of these measures.

At first sight the Tsimane′ appear as a relatively egalitarian society. Like other Amazonian indigenous groups, the Tsimane′ have a preferential system of cross-cousin marriage (e.g., men marry mother’s brother’s daughter), which creates a thick and wide web of relatives linked by descent and by marriage. Households visit each other often within and across villages to enjoy each other’s company, or to exchange goods and information (Ellis, 1996; Gurven, 2002). The survey done in 2000 with 509 subjects in 58 villages shows that only 10% of adults lived in their village of birth. Constant visiting and migration between villages homogenizes many outcomes, such as traditional knowledge of plants (Reyes-García et al., 2003b).

Like other Amazonian populations, the Tsimane′ routinely share home-brewed beer (chicha). Any Tsimane′ can walk into a Tsimane′ household serving chicha and expect to be served. In the smaller village, people cook in open courtyards and shout when the meal is ready so neighbors and other family members can join in communal eating. Successful hunters share game with others. Eleven percent of all goods entering households came as gifts or as transfers from friends or relatives; those goods accounted for 6.7% of the total value of household consumption. Tsimane′ work in groups to set up the traps to fish with plant poison; people in the fishing expedition take the fish, they catch with their own catch (Pérez, 2001). In the five-quarter panel study, we also found that about a quarter of all fishing events with nets or with fish poison were done in groups. Communal work prevails in the construction and in the maintenance of schools, in hunting expeditions, in the cleaning of public places, and in preparation for village festivals. In some of the more isolated villages, villagers work together in some of the more arduous tasks such as felling trees at the start of the agricultural cycle.

As in other similar societies, among the Tsimane′ gift giving, communal labor, and labor help permeate daily interactions. The shares of households that made gifts during the week before the day of the interview were as follows: 71% of household gave home-brewed beer, 58% cooked food, 45% plantains, 42% meat, 37% rice, 32% fish, 31% manioc, 28% maize, and 12% gave medicines and seeds. During the week before the day of the interview, 22–26% of households helped others in chores, or engaged in communal hunting, fishing, miscellaneous work, and farming, 13% of households did errands for others, and 8% offered medical help. Only 7.5% of households did not make any gifts, 39.0% of households did not do any communal work or offer any labor help during the week before the day of the interview, and only 4.5% of households did not make either any gifts or offer any help. Thus, the Tsimane′ practice extensive reciprocity.

Offsetting public expressions of sharing and generosity one also finds evidence of accumulation and economic inequalities. The presence or lure of public schools, the encroachment of loggers, cattle ranchers, and colonist farmers moving into the Tsimane′ territory (Godoy et al., 1998), and debt peonage into which some of them have fallen with outside traders—all create incentives to move less spatially and to accumulate more material possessions. With a more sedentary lifestyle, the possibilities for accumulating wealth rise.[1] Even without the presence of markets, one finds a strong ethos of economic independence among households, reflecting the fact that most of the diet comes from farm and forest goods produced or extracted by each household, rather than from goods produced communally. Young men who have entered the formal labor market buy prestige commercial items, such as watches, radios, and bicycles. Tsimane′ in villages closer to towns build walls to enclose their homes and even put fences around their courtyards. To guard their material possessions, some put locks on their doors when they leave the village (Byron, 2003). Even in meals, one finds evidence of selfishness. Although one finds communal meals in smaller villages, people do not go out of their way to invite others to share in the meals. They often turn their backs to others when they eat (Ellis, 1996), and people in the more modern villages complain that neighbors do not share meat, and thus, violate expectations of proper social norms. Only 5% of the sample received help from kin or neighbors after unforeseen income shocks (e.g., crop loss). Though reciprocity and gift giving permeate Tsimane′ society, they do not gain salience when an individual confronts a personal misfortune.

There is further evidence of inequality (Table 1). The Gini coefficient for area deforested/person is 0.35, but the standard deviation is 0.11, with minimum and maximum values (not shown) of 0.09 and 0.79, suggesting much variation around mean measures of village income inequality. To assess inequality in other outcomes from a larger sample than the one used in this study, we used the survey of 2000 with 58 villages to compute village Gini coefficients for the following variables using the households as the unit of observation: (a) mean cash earning/person during the two weeks before the day of the interview, (b) mean value of wealth/person based on the value of 16 modern and traditional physical assets, and (c) annual value of rice output/person. We obtained the following Gini coefficients for the variables just described: cash earnings, mean = 0.54 (S.D. = 0.12), wealth, mean = 0.28 (S.D. = 0.09), and rice, mean = 0.47 (S.D. = 0.13). This evidence suggests that Tsimane′ society contains inequalities across and within villages in a wide range of economic outcomes despite extensive expressions of generosity.

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[1] Nomadic people generally have fewer material possessions because of the burden of having to carry them as they move from place to place.

3. Estimation

To estimate the effect of community variables on adult nutritional status, we regress indices of nutritional status by including only a dummy variable for each village. The step allows us to estimate the share of the variance of nutritional status explained by all fixed community attributes. We then put community variables (e.g., income inequality, village-to-town travel time) on the right side to estimate their correlation with nutritional status while controlling for village fixed effects.

The following equation is used to estimate the effect of income on adult nutritional status:

$$N_{it} = \alpha + \zeta I_{it} = 0 + \lambda \mathrm{HK}_{it} + \theta W_{it} + \delta S_{it} + \xi C_{it} + \mu_{it} \qquad (1)$$

where N_{it} is (four different) anthropometric indexes of nutritional status for adult *i* at time *t*, $I_{it=0}$ stands for income during the year 2000 ($t = 0$), the year before the first survey in 2001 (hence, $t = 1$ for 2001). Income is equated with the area deforested by the household divided by household size. HK is an index of modern human capital that combines schooling, math skills, plus skills reading, speaking, and writing Spanish (the national language). *W* stands for the value/person of their wealth in physical assets. *S* captures the subject's physical stature, or age and sex-standardized *z*-score of height for age. *C* stands for control variables, including the subject's age and sex and a full set ($N-1 = 36$) of village dummy variables to control for village fixed effects. We estimate parameters with clustering by village-year because households are nested in villages. When estimating the effect of village-level variables (Table 2), we do not use expression (1). Instead, we regress N_{it} on 36 village dummies with and without additional controls for selected village-level variables (e.g., village-town travel time).

Estimating the parameters of expression (1) poses difficulties because we cannot control for the role of unobserved fixed heterogeneity in endowments and preferences of households and subjects. For example, subjects with better nutritional status might clear more forest, so area deforested, even though lagged by one year, could be partly endogenous. With semi-nomadic populations that move frequently in search for better farmlands and hunting grounds, even village attributes become potentially endogenous. We found no convincing instrumental variables so the parameters we estimate could contain endogeneity biases of an unknown magnitude and direction.

4. Sample, variables, and methods of data collection

We draw on two waves of annual panel surveys collected from the same subjects during February–April of 2001 and 2002. To select villages for the initial study of 2001, we did a baseline survey in 2000 of 509 households in 58 villages. Of the 58 villages, we selected 37

Table 2

Effects of village income inequality, social capital, and other village-level attributes on anthropometric indicators of nutritional status among Tsimane′ adults (18+ years), 2001–2002: results of OLS regressions with village fixed effects

Explanatory variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
(A) Dependent variable: age and sex-standardized z-score of mid-arm muscle area (ZMAM)												
Inequality												
Gini		0.21								0.43		
CV			0.13								0.17°	
log deforestation (as proxy for income)				0.06								0.13
Soc Cap					−0.003					−0.0006	−0.01	−0.0006
Nurses						0.058¶				0.066*	0.04*	0.061*
Healers							0.047¶			0.048°	0.06°	0.045°
Travel								0.593		0.67°	0.566*	0613*
Population									0.008	0.00	0.005	0.005
R^2	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.16	0.16	0.17	0.18	0.17
Joint test										9.86¶	1.00¶	0.967¶
N	557	557	557	557	554	544	544	557	557	541	541	541
(B) Dependent variable: age and sex-standardized *z*-score of skinfolds (ZSUMSK2)												
Inequality												
Gini		0.28								0.17		
CV			0.05								0.03	
log deforestation (as proxy for income)				0.21*								0.17
Soc Cap					−0.003					−0.004	−0.004	−0.003
Nurses						−0.046°				−0.020	−0.023	−0.019
Healers							−0.021			−0.023	−0.024	−0.021
Travel								−0.620		−0.707¶	−0.678¶	−0.759¶
Population									−0.002	−0.0005	−0.0007	−0.001
R^2	0.13	0.13	0.13	0.14	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14
Joint test										8.15¶	8.11¶	9.38¶
N	559	559	559	559	556	546	546	559	559	543	543	543
(C) Dependent variable: body-mass index (BMI (kg/m^2) in logarithms)												
Inequality												
Gini		0.001								0.002		

CV			0.001								0.001	
log deforestation (as proxy for income)				−0.006								−0.004
Soc Cap					0.0008°					0.0007	0.0007	0.0006
Nurses						0.001				−0.00001	−0.00002	−0.0001
Healers							−0.002			−0.001	−0.001	−0.001
Travel								0.024		0.043*	0.043¶	0.046¶
Population									0.0002	0.0008	0.0008	0.0008
R^2	0.19	0.19	0.19	0.19	0.20	0.19	0.19	0.19	0.19	0.20	0.20	0.20
Joint test										5.41¶	5.41¶	0.605¶
N	554	554	554	554	551	541	541	554	554	538	538	538
(D) Dependent variable: age and sex-standardized height for age (ZHT)												
Inequality												
Gini		0.14								0.08		
CV			0.04								0.03	
log deforestation (as proxy for income)				0.02								−0.06
Soc Cap					−0.006*					−0.011¶	−0.011¶	−0.012¶
Nurses						0.043*				0.088¶	0.088¶	0.085¶
Healers							−0.0005			−0.017	−0.017	−0.020°
Travel								0.188		0.050	0.049	0.112
Population									−0.003	−0.003	−0.003	−0.003
R^2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16
Joint test										0.250*	2.53*	2.54*
N	557	557	557	557	554	554	544	557	557	541	541	541

Notes: Regressions are OLS with robust standard errors, constant and village dummies (not shown), and clustering by village-year. We do not show coefficients of 36 village dummy variables because we are mainly interested in their total joint explanatory power as reflected in the R^2 (that is why there are no coefficients reported in column [1], as none of the explanatory variables have been entered yet in the regression). Joint test is F-test for all community variables except village dummies. ¶, *, and ° significant at the 99, 95, and 90% confidence level.

villages for the 2001 survey. One village refused to participate, and we replaced it with another village of similar socioeconomic characteristics. In each village, we selected at random an average of eight households for the survey (S.D. = 3.25). In each household, we selected at random one of the two household heads to take anthropometric measures and to answer survey questions. For questions that pertained to the entire household, we allowed other household members present to correct or contribute to the answer provided by the household head.

Between 2001 and 2002, the sample of households shrunk by 18%, from 378 to 311. Households and people left the sample because they moved to another village to visit relatives or to hunt, or because they moved to logging camps, cattle ranches, or to towns in search of employment. Nine subjects died during the study. We tried to find attriters when they returned to the village or when they moved to another village, but we did not try to find those who left the Tsimane′ territory.[2] We assessed whether adults who left the sample differed in significant ways from adults who remained in the sample. Using only the first survey of 2001, we compared the mean of anthropometric indicators and socioeconomic and demographic characteristics for the two groups, and found no significant statistical difference between people who left and people who stayed in the sample.

The latest Bolivian Census (2002) estimates the Tsimane′ population at about 8000. If we use the 2001 survey to estimate the average household size (mean = 6.02; S.D. = 2.60), the Tsimane′ population would contain 1329 households. Since we surveyed 378 households in 2001, the study covered circa 28% of all Tsimane′ households.

We use the following anthropometric indices of adult nutritional status: (a) sex and age-standardized *z*-score of sum of triceps and sub-scapular skinfolds (ZSUMSK2), (b) sex and age-standardized *z*-score of mid-arm arm muscle area (ZMAM), (c) sex and age-standardized *z*-score of physical stature (ZHT), and (d) body-mass index (BMI; kg/m^2). We use US norms to standardize (a–c) (Frisancho, 1990). (a, b, and d) Capture measures of short-run nutritional status; (c) captures long-run nutritional status.

We use (a, b, and d) because they capture different dimensions of short-run nutritional status (Frisancho, 1990). The *z*-score of the sum of skinfolds (ZUMSK2) provides a measure of energy reserves as body fatness. Severe energy under nutrition correlates with low body-fat reserves. *z*-Scores of mid-arm muscle area (ZMAM) provide an index of lean body (muscle) development and protein reserves. With acute nutritional stress or protein deprivation, muscle wasting and low indices of arm muscularity will occur. Body-mass index provides a more general measure of under nutrition and risk of obesity. The *z*-score of height for age (ZHT) captures long-run nutritional status or past parental and own investment in the health and nutrition of the subject.

Dependent variables had low correlations among each other. Correlations between indices of short-run nutritional status were as follow: 0.22 for ZMAM and ZSUMSK2, 0.48 for BMI and ZSUMSK2, and 0.38 for BMI and ZMAM. Though low, the correlations were all statistically significant at the 99% confidence level. Correlation coefficients between indices of short-run nutritional status and the index of long-run nutritional status (age and sex-standardized height for age, ZHT) were lower and generally statistically insignificant: 0.15 for ZHT and ZMAM, −0.05 for ZHT and ZSUMSK2, and for 0.04 BMI and ZHT. Only the correlation between physical stature and ZMAM was statistically significant at the 90% confidence level or higher. Low correlation coefficients between dependent variables support the idea that the indices measure different dimensions of nutritional status.

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[2] A quarter of the attrition came from people in a village with a Catholic mission. They initially allowed us to interview them, but later, as a group, refused to participate in the study or to be interviewed a second time for reasons that remain unclear. Besides the households from the village with the Catholic mission, only one other household refused to take part in the 2002 survey.

Raw anthropometric measures likely had low random measurement errors because we trained surveyors how to measure physical stature, weight, arm-muscle area, and skinfolds. We regressed measures of physical stature, weight, and skinfolds against a full set of binary dummy variables for coders and found no evidence of coder bias at the 95% confidence level. We followed the protocol of Lohman et al. (1988) and measured all adults in light clothing without shoes or hats. We recorded physical stature (standing height) to the nearest millimeter using a portable stadiometer or a plastic tape measure, body weight to the nearest 0.2 kg using a standing scale, mid-arm circumference to the nearest millimeter using a plastic tape measure, and skinfold thickness to the nearest 0.5 mm using Lange callipers. Although anthropometric measures had low random measurement errors, age-standardized measures of mid-arm muscle area, physical stature, and skinfolds likely contain some random measurement errors because many subjects did not know their exact age.

The measure of income in small-scale, pre-industrial societies is problematic because of the prevalence of self-sufficiency. In their anthropometric study of smallholders in rural Oaxaca, Malina used principal-component factor analysis of assets, occupation, land holding, and demographic variables to create a summary measure of socioeconomic status (Little et al., 1988, 1989; Malina et al., 1983, 1985). Others have followed their procedure (Bogin et al., 2002; Crooks, 1994; Shell-Duncan and Obiero, 2000). We opted to treat socioeconomic variables in a disaggregated form because we want to identify the variables that mattered most.

Income is equated with the sum of the area of old and fallow forest cleared by the household the year before the interview, and divide the area deforested by the number of people in the household. The forest area cleared provides a rough proxy for yearly consumption or income because people clear forest to plant chiefly crops for subsistence and, to a lesser extent, for sale. This proxy likely had low measurement error because self-reports of area deforested correlate reliably with actual area deforested (Vadez et al., 2003). Yet area deforested/person underestimates true income because it excludes cash earnings from wages and from the sale of forest goods, domesticated animals, or goods from domesticated animals.

We use the Gini coefficient to estimate village income inequality and use the village as the geographical unit to estimate inequality because most daily interactions in indigenous Amazonian societies take place within the village. We use the Gini coefficient in the core regressions inasmuch as it has become standard in measuring inequality (Fields, 2001; Ray, 1998). We realize that the Gini coefficient was not designed to measure inequality in small-scale societies and that it may be imprecise owing to the small sample of observations in each village ($n = 37$, mean = 8.08, S.D. = 3.25, min = 2, max = 15). To overcome this limitation, we also use the standard deviation of the logarithm of income and the coefficient of variation of income.

Measures of human capital likely contain some random measurement error. We asked subjects about the maximum school grade completed, gave them tests to assess math, writing, and reading skills, and decided on speaking fluency in Spanish based on whether subjects needed a translator during the survey. We have no reason to doubt the accuracy of self-reports of the maximum school grade completed, but we have reasons to suspect that tests of skills did not capture true skills because our tests were academic rather than practical. For example, in the math tests we asked subject to perform abstract math operations (e.g., "how much is 12 divided by 3?") rather than to solve math problems with relevance in their daily lives.

Because we measured several dimensions of modern human capital and because we had a small sample size of observations, we used principal-component factor analysis to create a summary index for modern human capital. For schooling, and for skills in math, reading, speaking, and writing in Spanish, we estimated a Cronbach alpha of 0.91, suggesting that the variables reflected one underlying dimension of modern human capital. Principal-component factor analysis suggested that variables loaded heavily into the first factor, which had an eigenvalue of 3.72 that was six times larger than that of the second factor (0.65). We used varimax rotation to create the summary index of modern human capital used in the regression analysis. Although principal-component factor analysis makes it easier to pool different dimensions of modern human capital into a summary index, it has the drawback of making difficult the economic or the social interpretation of results. For instance, one cannot determine whether a one-unit increase in the index of modern human capital is a large or a small change.

To measure wealth in physical assets, we asked about the quantity of 8 traditional and 10 modern physical assets owned by the household, and valued the assets at the village selling price. If a village lacked a price, we used that of the closest village. We divided total household wealth by household size to obtain average individual measures of wealth.

We equate social capital with gift giving and with communal work or with work done for others by a household because gifts and communal work or labor help are the main expressions of generosity in pre-industrial, small-scale societies. We focus on behavior rather than on social norms because behavior is a more objective measure of social capital (Glaeser et al., 2000). To create the variable for social capital, we estimated the average expression of generosity in the village excluding the subject's household.

The control variable age likely had large random measurement errors as circa half of the subjects were uncertain of their age. This has two implications for the accuracy of the analysis. First, we use age to compute age and sex-standardized z-scores of some dependent variables, so parameter estimates for those variables, though unbiased, have larger standard errors. Second, in computing individual measures of deforestation or wealth from household aggregates, we had the option of using household size measured with the number of people in the household or household size measured with adult equivalents. Since the estimate with adult equivalents uses the age variable, it contains some random measurement errors as well. Consequently, we use the number of people in the household rather than adult equivalents to calculate individual values in the primary analysis.

Multicollinearity should not affect results because explanatory variables had low pair-wise correlation. Pair-wise correlation coefficients were as follows: 0.33 ($p < 0.001$) for wealth/person and deforestation/person, 0.12 ($p < 0.019$) for deforestation/person and summary measure of modern human capital from principal-component factor analysis, 0.07 ($p < 0.387$) for physical stature (ZHT) and deforestation/person, 0.03 ($p < 0.958$) for physical stature (ZHT) and modern human capital, and 0.01 ($p < 0.998$) for modern human capital and wealth/person.

5. Results

The results of regressions with anthropometric indices of adult nutritional status as dependent variables and 36 village dummy variables on the right side are shown in Table 2 (column [1]). In columns [2–4], we add three separate measures of village income inequality, including the Gini coefficient (column [2]), the coefficient of variation (column [3]), and the standard deviation of the logarithm of income (column [4]). In columns [5–9], we add one village variable at a time to the village fixed-effect model of column [1] (Kennedy, 1998). Village variables include social capital (column [5]), modern health-care workers (nurses) (column [6]), traditional healers (column [7]), travel time from village to town (column [8]), and village population size (column [9]). In columns [10–12], we present the results of the full model: village fixed effects (36 dummy variables) plus all the village covariates just mentioned. In columns [10–12], we use the Gini coefficient (column [10]), the coefficient of variation (column [11]), and the standard deviation of the logarithm of income (column [12]). The purpose of Table 2 is to assess the share of the variance in anthropometric indices of nutritional status explained by village attributes and to identify the village attributes that matter most.

We find that village attributes explain a low share of the variance in anthropometric measures of adult nutritional status beyond the village fixed effects (Table 2). The regressions with only the 36 village dummy variables (column [1]) suggest that unmeasured village attributes alone explained between 13 and 19% of the variation in nutritional status. Adding one covariate at a time (columns [2–9]) or all covariates at the same time (columns [10–12]) did not improve the explanatory power of village variables. Village variables explained a greater share of the variance of BMI (19–20%) than the share of the variance of age and sex-standardized z-scores of mid-arm muscle area (ZMAM) (16–18%), physical stature (ZHT) (15–16%), or skinfolds (ZSUMSK2) (13–14%).

Moreover, conditioning for village fixed effects, measured village explanatory variables did not correlate significantly or consistently with anthropometric indices of nutritional status (Table 2). Nurses and traditional healers in a village correlated significantly with better scores of mid-arm muscle area (ZMAM), but did not do so with body-mass index or with age and sex-standardized z-scores of skinfolds (ZSUMSK2). The regression with physical stature as a dependent variable suggests that nurses correlated positively with physical stature and traditional healers correlated negatively with physical stature. Village-to-town walking time correlated positively with age and sex-standardized z-scores of mid-arm muscle area (ZMAM) and with body-mass index, but negatively with age and sex-standardized z-scores of skinfolds (ZSUMSK2). Although individual village variables did not show a strong, consistent correlation with anthropometric indices of nutritional status, they were jointly significant. Under the row “Joint test” for columns [10–12] with the full model (i.e., 36 village dummies plus all measured village variables), we see that measured village independent variables, as a group, correlated in statistically significant way with anthropometric indices of adult nutritional status (Table 2).

The method for measuring inequality did not affect results. All three measures of village income inequality (Gini coefficient, the coefficient of variation, and the standard deviation of the logarithm of income) generally correlated positively with anthropometric indices of adult short-run nutritional status, but results were rarely statistically significant (Table 2).[3]

Thus, these results suggest that aside from village-to-town walking time, measured village variables—income inequality, village population size, and social capital—did not correlate strongly or reliably by themselves with anthropometric indices of nutritional status. These measured village attributes explained a small share of the within-population variation of adult nutritional status. However, village attributes jointly did matter. For these reasons, in the regressions that follow we start with a fixed-effects model, i.e., 36 village dummy variables and then add the measured village variables of Table 2. In Table 3, we show the parameter estimates of Eq. (1). In column [1] of Table 3, we show results only with individual and household covariates. In column [2], we add 36 village dummy variables, and in column [3], we add the individual village variables of Table 2. Three findings stand out.

First, modern human capital correlated positively and significantly with all short-run measures of nutritional status. An increase of one unit in the index of modern human capital correlated with an increase of 0.09–0.10 S.D. in age and sex-standardized *z*-scores of mid-arm muscle area (ZMAM), with an increase of 0.06–0.08 S.D. in age and sex-standardized *z*-scores of skinfolds (ZSUMSK2), and with an increase of 1.2–2.1% in body-mass index. All results were statistically significant at the 95% confidence level or higher. The evidence in panel D suggests that modern human capital did not correlate with physical stature.

Second, wealth correlated with improvements in two measures of adult short-run nutritional status: age and sex-standardized *z*-score of skinfolds (ZSUMSK2) and body-mass index. A 1% increase in the value of wealth/person correlated with an improvement of 0.07–0.09 S.D. in ZSUMSK2. A doubling in the value of wealth correlated with an approximate improvement of 1.1–1.6% in body-mass index. Results were significant at the 90% confidence level or higher.

Third, area deforested/person and sex and age-standardized score of height bore no consistent, significant correlation with anthropometric indices of adult short-run nutritional status. Area deforested/person correlated negatively with age and sex-standardized *z*-score

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[3] Since measures of village income inequality may be imprecise in villages with a small sample of observations, we re-estimated models [2–4] and [10–12] by restricting the sample to villages with five or more observations. We found that coefficients became smaller and less statistically significant than in Table 2, but none of the results changed substantially. While village variables may not correlate with anthropometric measures of nutritional status in the pooled sample, they may correlate with nutritional status among subjects with worst nutritional status. To explore this notion, we re-estimated the regressions in column [10], but only for the bottom 25% of the nutritional status. In the regressions with ZMAM or ZHT as dependent variables, only the number of modern health-care workers continued to show a positive correlation. In the regressions with sum of skinfolds (ZSUMSK2) and body-mass index as dependent variables, travel time from village to town remained statistically significant. In short, we find little evidence to suggest that village variables correlate more strongly with anthropometric indices of nutritional status among subjects at the bottom of the distribution of nutritional status.

Table 3
The effect of wealth, human capital, and income on anthropometric indices of nutritional status among Tsimane′ adults (18+ years), 2001–2002: results of OLS regressions

Explanatory variables	[1]	[2]	[3]
(A) Dependent variable: *z*-score of mid-arm muscle area (ZMAM)			
log deforestation (as proxy for income)	−0.03	0.002	−0.007
Physical stature (ZHT)	0.22***	0.23***	0.24***
Human capital	0.09***	0.09***	0.10***
log wealth	0.07	0.05	0.06*
N	536	536	523
R^2	0.39	0.51	0.52
Village fixed effects	No	Yes	Yes
Village explanatory variables	No	No	Yes
(B) Dependent variable: *z*-score of skinfolds (ZSUMSK2)			
log deforestation (as proxy for income)	−0.01	−0.04*	−0.04*
Physical stature (ZHT)	−0.01	0.006	0.004
Human capital	0.06***	0.08***	0.07***
log wealth	0.07**	0.09***	0.09***
N	537	537	524
R^2	0.14	0.31	0.31
Village fixed effects	No	Yes	Yes
Village explanatory variables	No	No	Yes
(C) Dependent variable: body-mass index (BMI (kg/m^2) in logarithms)			
log deforestation (as proxy for income)	0.006	0.007	0.007
Physical stature (ZHT)	0.003	0.003	0.005
Human capital	0.01**	0.02***	0.02***
log wealth	0.01**	0.01*	0.01*
N	534	534	521
R^2	0.03	0.24	0.25
Village fixed effects	No	Yes	Yes
Village explanatory variables	No	No	Yes
(D) Dependent variable: *z*-score of physical stature (ZHT)			
log deforestation (as proxy for income)	0.04	0.08*	0.07
Physical stature (ZHT)			
Human capital	−0.02	−0.02	−0.01
log wealth	0.03	0.02	0.01
N	537	537	524
R^2	0.02	0.17	0.18
Village fixed effects	No	Yes	Yes
Village explanatory variables	No	No	Yes

Note: Regressions are OLS with clustering by village-year. *, **, and *** significant at the 90, 95, and 99% confidence level. Coefficients for control variables, constant, year, age, sex, and household size are not shown. Village fixed effect includes 36 village dummy variables, while village explanatory variables include all those used in column [10], Table 2.

of skinfolds (ZSUMSK2) and positively with physical stature (ZHT). A 1% increase in area deforested/person correlated with a decrease of 0.04 S.D. in skinfolds (ZSUMSK2) and with an increase of 0.08 S.D. in physical stature (ZHT), but results were significant only in a few of the models. Physical stature (ZHT) as an explanatory variable bore no significant correlation with either body-mass index or with skinfolds (ZSUMSK2), but it correlated positively with age and sex-standardized *z*-scores of mid-arm muscle area (ZMAM). An improvement of 1 S.D. in physical stature correlated with a 0.22–0.24 higher S.D. in age and sex-standardized *z*-score of mid-arm muscle area (ZMAM).

In sum, intra-population variance in short-run nutritional status correlated more strongly and reliably with variables associated with individual human capital and wealth, than with area deforested/person. We found virtually not significant relations between physical stature (ZHT) and area deforested, wealth, or modern human capital.

In Table 4, we report the results of sensitivity analysis to assess whether the results just discussed hold up under different model specifications or definitions: (a) In the sensitivity

Table 4
Sensitivity analysis

Explanatory variables	Dependent variables			
	ZMAM	ZSUMSK2	BMI	ZHT
Baseline results: column [2] of Table 3				
Human capital	0.09***	0.08***	0.02***	−0.02
log wealth	0.05	0.09***	0.01*	0.02
Promax rotation				
Human capital	0.09***	0.08***	0.02***	−0.02
log wealth	0.05	0.09***	0.01*	0.02
Adult equivalents				
Human capital	0.09***	0.08***	0.02***	−0.02
log wealth	0.05	0.09***	0.01*	0.02
Income = area sown with rice				
Human capital	0.09***	0.08***	0.02***	−0.02
log wealth	0.05	0.09***	0.01	0.01
Addiction				
Human capital	0.09***	0.08***	0.02***	−0.01
log wealth	0.05	0.09***	0.01*	0.02
Hygiene and housing quality				
Human capital	0.12**	0.03	0.01**	−0.008
log wealth	0.06	0.09	0.02*	−0.06
Exclude pregnant women				
Human capital	0.09***	0.07***	0.02***	−0.01
log wealth	0.06*	0.08***	0.01*	0.01
All controls except hygiene and housing quality				
Human capital	0.10***	0.08***	0.02***	−0.01
log wealth	0.05	0.09***	0.01*	0.02
All controls with hygiene and housing quality				
Human capital	0.12*	0.05	0.02**	0.02
log wealth	0.04	0.08	0.01*	−0.08

Notes: Regressions are the same as in column [2] of Table 3, except for changes indicated in the headings. For example, in the regressions called ‘Exclude pregnant women’, we use the regression of column [2] of Table 3 but exclude pregnant women.

analyses, we used promax instead of varimax rotation in the principal component factor analysis to obtain summary measures of modern human capital. Varimax and promax refer to rotation methods to obtain simpler structures from factor loadings. Varimax relies on orthogonal rotation and maximizes the variance of the squared loading for each factor. Promax relies on varimax-rotated loadings to obtain oblique rotation, but allows correlation between factors (Hamilton, 1992); (b) we used adult equivalents instead of using the number of people in the household to obtain individual measures of income and wealth from household aggregates. Adult equivalents might be a better reflection of household work capacity and household needs; (c) we used area sown with rice/person instead of using total area deforested/person as in all other regressions. As the principal cash crop in the area, area sown with rice should proxy reliably with cash earning; (d) since important health-related behavior could affect anthropometric indices of adult nutritional status, we added the following two variables: number of cigarettes smoked and number of times subjects drank commercial alcohol during the week before the day of the interview; (e) we controlled for household hygiene and housing quality by adding two dummy variables for household hygiene, whether the household had a latrine and a kitchen table, and adding two variables from principal-component factor analysis to reflect the quality of housing material. We did not include measures of hygiene and housing quality in the regressions of Table 3 because we assessed housing quality only during the second year, so including the variables in the regressions of Table 3 would have reduced the sample size by more than one half. (f) We excluded pregnant women because pregnancy changes anthropometric indices of short-run nutritional status. As a last check, we included all of the above controls. Regressions in Table 4 are similar to the regressions in column [2] of Table 3, except for the changes just noted.

The results did not differ from the results of Table 3. Modern human capital always correlated positively with all three measures of adult short-run nutritional status. Wealth correlated positively with age and sex-standardized *z*-scores of skinfolds (ZSUMSK2) and with body-mass index, but not with age and sex-standardized *z*-scores of mid-arm muscle area (ZMAM). Results even held up when including all the changes together, but except for variables measuring hygiene and housing quality. When including variables for hygiene and housing quality, results became weaker, probably because the sample size shrank by more than a half. In none of the regressions did physical stature (ZHT) correlate with modern human capital or with wealth.

Since modern human capital correlated so consistently and strongly with improved measures of adult short-run nutritional status, we next tried to identify the type of modern human capital that mattered most, and the most significant interactions between different skills associated with modern human capital. To do so, we re-estimated the regressions of column [2], Table 3, without the summary index of modern human capital, but with schooling, individual measures of modern human capital, and with interaction terms between skills. We found that individual skills and schooling rarely correlated positively and significantly with anthropometric measures of adult short-run nutritional status, but together all skills and schooling correlated with age and sex-standardized *z*-scores of skinfolds (ZSUMSK2; $F = 3.37$; $p < 0.008$) and with body-mass index ($F = 4.34$; $p < 0.001$). Skills and schooling together bore a weaker joint correlation with age and sex-standardized *z*-score of mid-arm muscle area (ZMAM; $F = 1.62$; $p < 0.167$).

Controlling for skills and schooling, we then added one interaction term between skills at a time. We found no consistent pattern with interaction terms across anthropometric outcomes. From this, we tentatively conclude that the positive effect of the summary index of modern human capital on anthropometric indices of short-run nutritional status in Tables 3 and 4 probably comes from the effect of all dimensions of modern human capital acting together rather than from the direct effect of schooling or individual academic skills, or from the interaction effect between different skills.

Wealth can contribute to better nutritional status by allowing households to smooth consumption in the face of idiosyncratic income shocks (e.g., selling assets) or by contributing directly to the diet (e.g., greater consumption of animal products). We cannot test the role of wealth in consumption smoothing because we do not have many repeated measures from the same subjects. In the five-quarter panel study of two villages, we measured income shocks and household's response to shocks. Those results suggest that households did not liquidate or consume assets when faced with idiosyncratic income shocks. For this reason, the effect of wealth on own adult short-run nutritional status probably has to do more with the direct contribution of assets to short-run nutritional status (e.g., eating animals or animal products from one's stock) than with the role of assets to smooth consumption.

Since wealth correlated consistently and positively with two of the three anthropometric measures of short-run nutritional status (age and sex-standardized *z*-score of skinfolds and body-mass index), we next explore the type of wealth the mattered most. We disaggregated the wealth variable into three parts: (a) wealth in domesticated animals (cows, ducks, hens, and pigs), (b) wealth in foraging technology (bows, canoes, fishhooks, fishnets, rifles, and shotguns), and (c) wealth in all other physical assets (cotton bags, rice grinders, axes, bicycles, metal knives, machetes, mosquito nets, metal pots, and radios). We re-estimated the regressions in column [2] of Table 3 without the measure of total wealth; instead we added the three dimensions of wealth just described (Table 5).

Table 5
Effects of wealth in domesticated animals, technology, and in other assets on nutritional status among Tsimane′ adults (18+ years), 2001–2002: results of OLS regressions

Explanatory variables, log of wealth in	Dependent variables			
	ZMAM	ZSUMSK2	BMI	ZHT
	[1]	[2]	[3]	[4]
Animals	0.02	0.03*	0.002	−0.004
Technology	0.01	0.02	0.008*	0.04
All other assets	−0.01	0.03	−0.004	−0.07
Joint test				
Animals and technology	1.12	2.33*	1.99	1.20
R^2	0.51	0.32	0.25	0.19
N	484	485	482	485

Notes: Regressions are similar to regressions in column [2] of Table 3, except we split wealth into animals, foraging technology, and all other assets. Animals include cows, ducks, hens, and pigs. Foraging technology refers to bows, canoes, fishhooks, fishnets, rifles, and shotguns. Other assets include cotton bags, rice grinder, axes, bicycles, metal knives, machete, mosquito nets, metal pots, and radios. Under test of joint significance we report the *F*-statistics and the probability of exceeding the *F*-critical value.

Results suggest that wealth in animals correlated with improved measures of age and sex-standardized *z*-scores of skinfolds (ZSUMSK2). A 1% increase in animal wealth correlates with a 0.032 higher S.D. in age and sex-standardized *z*-scores of skinfolds (ZSUMSK2). Although foraging technology did not correlate significantly with nutritional status in the regression with age and sex-standardized *z*-scores of skinfolds as a dependent variable, foraging technology and wealth in domesticated animals jointly correlated positively and relatively significantly with measures of skinfolds (ZSUMSK2; $F = 2.33$; $p < 0.104$) and, less significantly, with body-mass index ($F = 1.99$; $p < 0.144$). We did further analysis to see if we could identify the domesticated animals that drove the results. We regressed anthropometric indices against all assets separately, plus a full set of village dummies. No animal or asset correlated consistently across all three anthropometric indicators of short-run nutritional status.

In sum, the evidence suggests that access to both foraging technology and wealth in domesticated animals might contribute slightly to better own adult short-run nutritional status. The coefficients of Table 5 are small. If one were to double both the value of a person's stock of domesticated animals and the value of their foraging technology, body-mass index would improve by only about one percent. Unfortunately, we cannot work backward and identify or explain variation in household wealth in animals or in foraging technology. Asset choices and nutritional status could both reflect the role of third variables (e.g., nutrition knowledge) that we did not measure.

We tested for structural heterogeneity to decide if the effects of modern human capital and wealth varied by sex or by village-to-town travel time, and whether wealth and modern human capital interacted in a significant way. We found no significant, consistent interaction effects across the four outcomes, suggesting that the pooled results suffice.

So far we have focused mainly on anthropometric measures of adult short-run nutritional status. The regressions of panel D in Table 3 suggest that the log of income was significant, but only in model 2. Besides the log of income, we found that only age bore a consistent and statistically significant correlation with physical stature across all models (coefficient not shown). An additional year of age correlated with a 0.006–0.007 higher S.D. in age and sex-standardized *z*-scores of height and results were statistically significant at the 95% confidence level or higher.[4]

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[4] In addition, since income could be endogenous to nutritional status, we explore the effect of an instrumental-variable approach. As a proxy for income, we used cash earnings from wage labor and from the sale of all goods for the 2 weeks before the day of the interview. We instrumented cash earnings with the number of outside traveling traders the household came in contact during the month before the day of the interview. Traders correlated reliably with higher cash earnings because they offer employment, supply credit, and buy goods. We also found that traders did not directly affect nutritional status, except through income. We ran two-stage least squares with traders as an instrument for cash earnings and found no significant effect of instrumented cash earnings on anthropometric measures of short-run nutritional status, confirming the notion that income, whether defined as area deforested/person or as cash earnings, bore no strong, obvious correlation with adult measures of short-run nutritional status. We do not put too much emphasis on the results of two-stage least squares regression because traveling traders could be endogenous if villagers self-select to interact with them in market transactions. Also, the presence of traders in a village and a villager's willingness to sell to a trader might both reflect the effect of a positive endowment shock (e.g., a bountiful harvest) that we did not measure.

6. Conclusions

We draw two tentative conclusions from the analysis. First, measured village variables (nurses, traditional healers, population size, social capital, travel time to the nearest village) explain a low share of the variance in anthropometric measures of adult nutritional status. Second, individual variables play a more prominent role, particularly variables associated with modern human capital and wealth. Thus, contrary to our expectations, individual resources did not get diluted in the village as a consequence of social norms of reciprocity. In other words, even in highly autarkic societies; such as the Tsimane′ of Bolivia, with strong social norms of reciprocity, individual resources embedded in modern forms of human capital and household wealth protect one's own short-run nutritional status. Except for age, we did not find individual variables that explained variation in adult physical stature.

The analysis of within-population variance sheds some light on why rural peoples in the early stages of industrialization in Europe and North America might have had better health than their urban counterparts and poses questions for future research. The information presented does not bear out some hypotheses from the historical record of industrial nations. For example, we find no evidence that the availability of farmland matters among the Tsimane′ because the Tsimane, like most native Amazonian societies, have large amounts of land available relative to people, i.e., enjoy a low population density (Davis and Wali, 1993). We find no evidence that income inequality or village population size matters in shaping adult nutritional status, though the conclusion could change if one examined the role of income inequality over a larger geographical unit than the village. Our results resemble those of Malina et al. among smallholders in Oaxaca, Mexico (Little et al., 1988; Malina et al., 1985). They found that growth rates of anthropometric indices often did not differ across children of different socioeconomic status. Nor do we find evidence that hygiene matters a lot in this setting. In contrast, Europe, pre-Hispanic Mexico, 19th-century North America, and in many cities of the developing world, infectious diseases from population growth, poor nutrition, and unhygienic conditions scourged urban dwellers (Bogin, 1988; McNeill, 1976). Unsanitary conditions in cities caused poor nutritional status among the population.

Instead, we find some indirect evidence to suggest that it was probably the quality of the diet that mattered, particularly access to animal protein, fish, game, or meat (or meat products) from domesticated animals. We did not measure the consumption of animal protein that individuals consumed, so we cannot test the hypothesis in a direct way, but animal protein emerges as a likely candidate since households with greater wealth in domesticated animals had better adult measures of short-run nutritional status, though the magnitude of the effect was small and results were marginally significant in some cases. Future studies in anthropometrics should probably focus on dietary quality, particularly the consumption of animal proteins between rural and urban populations. Articles by Brinkman, Drukker, Haines, Craig, Weiss, and Cuff in the book by Komlos and Baten, *The Biological Standard of Living in Comparative Perspective*, already provide empirical evidence for the role of protein consumption in shaping anthropometric indicators in contemporary developing nations and in 19th-century

North America.[5] A more complete understanding of urban-rural differences in nutritional status during the early stages of industrialization will probably begin to emerge when we combine anthropometric history with the historical study of ethnobiology, ethnozoology, and ethnomedicine.

Recent years have seen an upsurge of interest in industrial nations in the role of community variables, such as income inequality and social capital, in shaping individual health. The interest has done much to shift attention away from canonical determinants of health, such as income and human capital, which have served well until now. Growing evidence from industrial nations has started to accumulate suggesting that the effect of income inequality and social capital on health is often ambiguous or weak (Lynch et al., 2004a,b). The case study of the Tsimane′ suggests that, at least for populations in developing nations, a reappraisal of the emerging orthodoxy is warranted before dropping more conventional explanations.

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[5] In 19th-century rural Europe, Japan, and North America, some of the animal proteins consumed by rural populations probably came from fishing and hunting, so future studies should assess the availability of animal biomass in the wild and the availability of foraging technologies to households since the technologies would shape the intake of animal proteins in the household. It is probably a mistaken diagnosis to assume that the consumption of animal proteins before industrialization came only from domesticated animals. Rural peoples in 18th and 19th-century Europe, Japan, and North America probably had a great deal of folk, traditional, or tacit knowledge of medicinal plants and animals and wild foods for use in lean times. Based on observations, experience, and on oral communication, this knowledge probably accumulated over generations to protect individual health and consumption. At present, parents and children in many developing nations self medicate with local plants (Berlin and Berlin, 1996; Geissler et al., 2000; Sternberg et al., 2001). The practice is not unique to humans. Some of the great apes also self medicate with wild plants (Huffman, 1997; Wrangham, 1995), and the same may have been true in rural areas of industrialized nations during the early stages of industrialization. When rural people moved to cities, they probably started to forget useful traditional knowledge related to health and nutrition. Perhaps not the first migrants to cities, but certainly their children and their descendants in urban settings probably knew less and less about the role of medicinal plants and animals. With less folk knowledge, with inadequate access to modern health-care services in cities, and without modern concepts of modern health and hygiene, new migrants to cities and their descendants may have been in the worst of all possible worlds despite higher income. The spread of schooling and modern concepts of hygiene eventually improved health and nutritional status for most, but there may have been a hiatus during which people with shrinking stocks of traditional knowledge may have lacked useful (albeit traditional) human-capital skills to protect their nutritional status and their health and, in consequence, fared worse than others.

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