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Victoria Reyes-García [ab]; Thomas McDade [c]; Vincent Vadez [b]; Tomás Huanca [b]; William R. Leonard [c]; Susan Tanner [c]; Ricardo Godoy [b]
[a] ICREA and ICTA, Universitat Autònoma de Barcelona, Spain
[b] Brandeis University, USA
[c] Northwestern University, USA

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Non-market Returns to Traditional Human Capital: Nutritional Status and Traditional Knowledge in a Native Amazonian Society

VICTORIA REYES-GARCÍA*, **, THOMAS McDADE***,
VINCENT VADEZ**, TOMÁS HUANCA**,
WILLIAM R. LEONARD***, SUSAN TANNER****, &
RICARDO GODOY**
*ICREA and ICTA, Universitat Autònoma de Barcelona, Spain, **Brandeis University, USA,
***Northwestern University, USA, ****University of Georgia, USA

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ABSTRACT *In industrial economies schooling produces positive non-market returns but do traditional forms of human capital also produce such returns, and do schooling and traditional human capital act as complements or substitutes in their association with well-being? Drawing on data from 450 adults (16+ years of age) from an indigenous Amazonian society in Bolivia, we estimate the association between traditional plant knowledge and nutritional status as measured by body-mass index. After conditioning for many covariates, we find that doubling an adult's traditional knowledge is associated with a mean improvement in BMI of 6.3 per cent; the association is stronger for unschooled adults and for those living far from the market town. Though schooling bore a negative association with traditional knowledge, those two forms of human capital had independent associations with BMI. The analysis suggests that schooling does not necessarily undermine the accumulation of traditional knowledge.*

I. Introduction

In industrial economies, schooling and the skills and behaviours learned in school produce positive, private non-market returns (Wolfe and Zuvekas, 1997; Wolfe and Haveman, 2001; Bonjour et al., 2003) but, do traditional forms of human capital also produce such returns? For most of human history, people's main form of human capital has not been schooling or the skills and behaviours learned in school but local knowledge of plants, animals and the environment that accumulated over

Correspondence Address: Victoria Reyes-García, ICREA Researcher, Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, 08193 Bellaterra, Barcelona, Spain. Email: victoria.reyes@uab.es; vreyes@brandeis.edu

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generations. Researchers have argued that local knowledge helps people deal with pest infestations (Bentley and Rodriquez, 2001), cope with weather shocks (Colson, 1979; Kuhnlein and Turner, 1991), select cultivars (Brush, 1995), manage natural resources (Atran and Medin, 1997; Berkes, 1999; Medin and Atran, 1999; Berkes et al., 2000; Huntington, 2000) and enhance health and nutritional status (Jackson, 1996; Johns, 1996, 1999; Etkin, 2000). These studies suggest that traditional knowledge might produce positive non-market returns but none of the studies contains quantitative estimates of the returns associated with this ancient form of human capital.

Here we take a first step in the study of the individual benefits of traditional human capital. We provide an estimate of the private non-market returns to traditional knowledge among adults in a highly autarkic society of hunters, gatherers and horticulturalists in the Bolivian Amazon. We focus on non-market returns and theoretical knowledge of plants for various reasons. We focus on a non-market outcome, body-mass index (BMI; kilogrammes/metres^2), because market outcomes, such as earnings, contain selectivity biases in autarkic societies (Deaton, 1997). In our sample, 51 per cent of adults did not earn cash. BMI is a reliable and valid indicator of general short-run nutritional status among adults (Shetty and James, 1994) and is considered useful in predicting morbidity, work capacity and mortality (Ferro-Luzzi et al., 1992; WHO, 1995). We equate the term traditional knowledge with theoretical knowledge of wild and semi-domesticated plants. We focus on theoretical knowledge rather than on the ability to use that knowledge because studies suggest that native peoples acquire most of their theoretical knowledge before adolescence (Stross, 1973; Hunn, 2002; Zarger, 2002). Therefore, theoretical knowledge should be less endogenous than the ability to use that knowledge, which might show greater responsiveness to uses over the life cycle. Last, we focus on plants rather than on other fields of knowledge (such as animals, soils) because traditional knowledge of plants is most likely to affect health and nutritional status in native Amazonian societies (Johns, 1996; Etkin, 2000; Pieroni and Price, 2006).

The study of the non-market returns to traditional knowledge is important for two reasons. First, estimates of the non-market returns to this form of human capital should help explain the cultural transmission of knowledge across generations. The private non-market returns to traditional human capital and schooling among adults should inform parents as to how to allocate investments in their children so their children accumulate the mix of cultural stocks that will provide them with the greatest benefits as adults (Boyd and Richerson, 1985; Castro and Toro, 2004). For example, if private returns to schooling overshadow private returns to traditional knowledge, then parents might be likely to steer their children to attend school and acquire academic skills and behaviours rather than learn traditional knowledge. Or the other way around, if private returns to traditional knowledge overshadow private returns to schooling, parents might ensure that their children acquire traditional knowledge but not modern human capital. The difference in the private returns between traditional human capital and schooling has implications for rates of retention and transmission of traditional knowledge across generations.

Second, the study of the non-market returns to traditional knowledge allows one to assess whether schooling and traditional knowledge act as complements or as substitutes in shaping non-market outcomes. Researchers argue that traditional knowledge, like language, deserves preservation because it represents humanity's heritage and diversity (Maffi, 2001, 2002). Several reasons might contribute to the loss of traditional knowledge, with schooling a possible culprit. Studies from developing nations suggest that schooling bears a negative association with traditional knowledge possibly because people face tradeoffs as they invest in the accumulation of traditional knowledge or schooling (Sternberg, 1997; Benz et al., 2000; Sternberg et al., 2001; Zent 2001). Time and resources invested in school deflect from time and resources invested in the accumulation of traditional knowledge because people cannot be in two places or study two topics at the same time (Sternberg 1997; Sternberg et al., 2001). Researchers have estimated the association between traditional knowledge and schooling but they have yet to do a formal test of whether the two forms of human capital complement or substitute for each other in shaping well-being. A better understanding of the association between schooling and traditional knowledge has the potential to help in the design of school curricula so schooling and traditional knowledge reinforce rather than undermine each other (Lipka et al., 2001).

II. Subjects and Methods

Research on the returns to traditional knowledge among the Tsimane' forms part of an ongoing longitudinal study that started in 1999, which investigates the effects of markets on well-being. Information for this article comes from five consecutive quarterly surveys carried out among the same participants between August 2002 and November 2003. Since we collected information on theoretical plant knowledge only during the third quarter (December 2002–February 2003), we do the analysis with variables for that quarter, except for variables on modern human capital, which we collected during the first quarter.

The People

The Tsimane' are a native Amazonian society of about 8,000 people living in about 100 villages in the department of Beni in the Bolivian Amazon. Tsimane' live along riverbanks and logging roads in villages of about 24 households. Subsistence centres on hunting, fishing and shifting slash-and-burn farming (Vadez et al., 2004).

Tsimane' have low income, are highly autarkic and depend heavily on plants. In a previous study (Godoy et al., 2002), we found that the mean annual income from cash earnings and from the imputed value of farm and forest goods consumed from their own fields and forests reached US$ 332/person, a third of the average income in Bolivia (US$ 980/person), one of the poorest nations in Latin America. We also found that wild and domesticated plants accounted for 51–58 per cent of the total value of consumption. Goods bought in the market accounted for only 2.7 per cent of the total value of consumption.

Though highly autarkic, the Tsimane' display variance in participation in the market economy. To earn cash, Tsimane' work as unskilled labourers in logging camps, cattle ranches and, in the homesteads of colonist farmers. They also earn cash by selling crops and forest goods (Vadez et al., 2004). Eighty four per cent of participants reported travelling to market towns at least once a year, and only 2 per cent did not own any commercial assets (for example, metal pots). Modern technologies of farm production are limited to new varieties of rice introduced by missionaries, industrial dibbles and the sporadic use of herbicides.

Tsimane' have wide and deep knowledge of local wild plants. We have documented 233 plant species with a total of 355 different uses (Reyes García et al. 2005). The Tsimane' use plants for many aspects of their daily life including medicine, firewood, house construction, tools and food. They acquire most of their theoretical knowledge of plants before adolescence but among Tsimane' adults, an additional year of age is associated with a 0.5 per cent ($t = 1.80$, $p = 0.72$) increase in plant knowledge. For example, if a Tsimane' knows 100 plants at 16 years of age, by the age of 65, this individual will know only 24 more plants. Tsimane' apply their knowledge of medicinal plants frequently. Byron (2003), for instance, found that the Tsimane' treated most common illnesses with plants rather than with Western medicines.

Indices of adult short-run nutritional status among Tsimane' are low relative to standards from industrial nations. Age and sex-standardised z scores of mid-arm muscle area, height-for-age, sum of triceps and sub-scapular skinfolds and, weight-for-age are below norms from the United States (Foster et al., 2005): 41 per cent of adults are stunted, or two standard deviations below the height-for-age norm from the United States (Foster et al., 2005).

Sample

Participants for the study included all people over the age of 16 in all households ($n = 213$) of 13 villages along the Maniqui river, department of Beni. We selected villages at different distances from the market town of San Borja (population 19,000) to capture cross-sectional variance in participation with the market economy. We had 450 adults (women = 235; men = 215) with complete information on body-mass index and plant knowledge, so we report information only for this sub-sample.

Methods of Data Collection

We used formal interviews to get estimates of plant knowledge and control variables. We collected anthropometric information to get estimates of nutritional status. Four female and four male researchers collected the information. Seven of the eight researchers lived continuously in the study site for the duration of the study, and four had lived longer in the sites as part of the longitudinal study. Three of the researchers spoke Tsimane' moderately well, but they all used translators for the interviews.

Body-mass Index. We followed the protocol of Lohman et al. (1988) and measured subjects in light clothing without shoes or hats. We recorded stature (standing height) to the nearest millimetre using a portable stadiometer. Due to logistical problems for transporting the equipment, in the isolated communities we used a plastic tape to record stature. We measured body weight to the nearest 0.20 kg using a standing scale.

Plant Knowledge. To measure the traditional knowledge of plants we provided participants with the Tsimane' name for 19 local useful plants and asked them whether they knew each plant. We had previously established whether the plants were useful for medicine, firewood, house construction, tools or food (Reyes García et al., 2006). If participants said they knew the name of the plant, we coded the answer as one; otherwise, we coded the answer as zero. We summed answers to the 19 questions to obtain a total score of traditional plant knowledge for each participant.

Modern Human Capital. Modern human capital included schooling, as defined by the maximum school grade attained by the subject. Other dimensions of modern human capital included maths skills, writing ability and fluency in spoken Spanish, Bolivia's national language. To assess maths skills we asked participants to add, subtract, multiply and divide in that order and stopped when the subject could not answer a question or answered incorrectly. We assigned a one to each correct answer, with scores ranging from zero to four. We judged writing ability by participant's ability to sign their name on a piece of paper provided during the interview. We coded answers to writing ability as follows: 0 = unable, 1 = with difficulty, 2 = well. Interviewers judged each participant's ability to speak Spanish and coded answers as follows: 0 = unable, 1 = with difficulty, 2 = fluent.

Control Variables. Age and sex were considered as control variables that are associated both with BMI and with plant knowledge. The age variable contained measurement errors: 24 per cent of subjects said they did not know their exact age but the proportion could be higher because few adults have birth certificates. Other controls in the regression models were household size and, days ill and days worked during the 8–14 days before the day of the interview. We measured household size with male-adult equivalents rather than with the number of people because male-adult equivalents capture better the nutritional status of the household (Deaton, 1997). We asked about the number of days worked in wage earning and about the number of days the participant had been bedridden during the 8–14 days before the day of the interview; we lagged the variables by seven days to reduce biases from possible reverse causality.

Estimation Strategy

For the empirical analysis, we assess the association between adult body-mass index (outcome variable) and: (a) a participant's own traditional knowledge; and (b) the interaction of schooling and traditional knowledge.

We used the following expression to model body-mass index:

$$\log BMI_{ihv} = \alpha + \gamma T_{ihv} + \psi MT_{ihv} + \beta M_{ihv} + \lambda P_{ihv} + \zeta H_{hv} + \eta C_v + \varepsilon_{ihv} \qquad (1)$$

$\log BMI_{ihv}$ is the logarithm of body-mass index of an adult, where i is the subject, h the household, and v the village. T_{ihv} captures the traditional knowledge of plants of the subject. MT_{ihv} captures the interaction of modern (M) and traditional human capital (T). M_{ihv} is a vector of variables for the subjects related to modern human capital including skills in maths and writing, fluency speaking Spanish and the maximum school grade completed. P_{ihv} is a vector of observed variables for the subject (for example, age and sex) that directly affects body-mass index. H_{hv} stands for household size. C_v is a set of village dummy variables to control for variables that could directly affect body-mass index and traditional knowledge; such variables could include plant diversity or proximity to markets. ε_{ihv} is a random error term that reflects stochastic shocks.

We use ordinary least squares with clustering of subjects by villages because people are nested in villages. Since we did not have instrumental variables for traditional knowledge we cannot infer causality from the parameters we estimate.

III. Results

Descriptive Statistics

Table 1 contains definitions and summary statistics for the variables used in the regressions.

Tsimane' adults fall in the normal range of BMI. The average participant had a body-mass index of 23.18 (std dev = 2.58). The mean falls in the 'normal/healthy' range of BMI for adults (between 18.5 and 24.9) (Shetty and James, 1994). BMI was slightly right-skewed (skewness coefficient = 0.73) and had a coefficient of kurtosis of 4.42. To normalise BMI and to make the interpretation of coefficients easier, we look at the natural logarithm of BMI. The variable for the natural logarithm of BMI had a coefficient of skewness of 0.27 and a coefficient of kurtosis of 3.88. When the outcome variable is in logarithms, we can read coefficients as a percentage change in BMI from a marginal change in the explanatory variable.

Tsimane' know much about wild plants. On a range from 0 to 19, the average participant scored 15 points in the test of traditional knowledge (std dev = 3.6). The mean score for men, 15.4 (std dev = 3.5), was slightly higher than the mean score for women, 14.7 (std dev = 3.8) and was statistically significant in a two-tailed t-test comparing the difference in the mean between the two samples ($t = 2.00$, $p < 0.04$).

The Tsimane' have low levels of schooling and academic skills. The average adult in the sample had completed 1.8 years of schooling (std dev = 2.2). The average adult man had 2.5 years of schooling (std dev = 2.6) and the average adult woman had only 1.21 years of schooling (std dev = 1.55). Thirty per cent of adult men and 50 per cent of adult women had no schooling. The mean value for maths skills was 1.0 (std dev = 1.4) and the median value was zero; 56.5 per cent of the sample scored a zero in the math test (men = 39.9%; women = 74.0%). Men scored an average of 1.5 points in the maths test (std dev = 1.7), four times higher than the mean score of women (mean = 0.5; std dev = 0.9). Nearly 60 per cent (58.9%) of subjects could not write, 13.6 per cent wrote with difficulty, and 27.5 per cent wrote well. Over one third (39.3%) of subjects could not speak Spanish, 29.7 per cent could speak it with difficulty, and 31.0 per cent could speak fluent Spanish.

Relation between Different Measures of Human Capital

We next explore the correlation between different dimensions of human capital. The results of Table 2 suggest a high, positive and statistically significant correlation

Table 1. Definition and summary statistic of variables used in regression analysis for Tsimane' Amerindians over 16 years of age during December 2002–February 2003 (n = 450)

Name	Definition	Mean	Std Dev
Dependent variable			
BMI	Body-mass index (kilogrammes/metres^2); in regression entered in logarithms	23.18	2.58
Explanatory variables: human capital			
Schooling	Maximum schooling achieved by subject	1.81	2.19
Math	Score in maths test; range 0 to 4	0.97	1.42
Writing	Ability to sign name (%)		
	Unable	58.9	
	With difficulty	13.6	
	Well	27.5	
Spanish	Ability to speak Spanish (%)		
	Unable	39.3	
	With difficulty	29.7	
	Fluent	31.0	
Plant knowledge	Score in test of plant knowledge; subjects asked if they new names of 19 plants; in regression entered in logarithms.	15.1	3.64
Explanatory variables: controls			
Male	Sex of subject; 1 = male; 0 = female	0.48	0.50
Age	Age of subject in years	34.8	15.29
Health	Self-reported person – days in bed from three main ailments during 8–14 days before interview	0.18	0.84
Work days	Number of days worked in wage labour during 8–14 days before the interview	0.48	1.58
Household size	Household size measured with male adult equivalents (n = 213)	4.10	1.89

between schooling and academic skills. Schooling, maths and writing had correlation coefficients of 0.70 (schooling-math), 0.66 (schooling-writing), and 0.76 (writing-math). Proficiency in spoken Spanish had slightly lower correlation coefficients with schooling and with academic skills, probably because people learn Spanish outside school. Correlation coefficients between Spanish, schooling, maths and writing were as follows: 0.46 (Spanish-schooling), 0.51 (Spanish-maths), and 0.56 (Spanish-writing).

The results of Table 2 also suggest a negative and statistically significant correlation between knowledge of plants and maths skills (-0.17) and between knowledge of plants and writing ability (-0.12). Knowledge of plants bore a low correlation with schooling (−0.10; p = 0.18) and with the ability to speak Spanish (−0.08; p = 0.43).

To explore further the relation between different types of human capital, we regressed the logarithm of traditional knowledge (dependent variable) against schooling, age, sex and a full set of village dummies, with a clustering of subjects by village. We then added one modern human capital skill at a time: math, writing and Spanish (Table 3). The results suggest that only maths skills bore an association with traditional knowledge. A one-point improvement in the maths score was associated with 2.2–2.7 per cent lower plant knowledge.

Bivariate Regressions

To advance our comparative understanding of how plant knowledge and schooling relate to BMI, we run a series of bivariate regressions (not shown). We regressed plant knowledge (explanatory variable) against the logarithm of BMI and find that plant knowledge by itself explains 2.36 per cent of the variance in adult BMI. In a similar regression but using schooling as an explanatory variable, we find that schooling explains only 0.02 per cent of the variance in adult BMI. So, although traditional knowledge explains a low share of the variance in BMI, it explains 100 times more of the variance in BMI than schooling.

Table 2. Correlation between schooling, academic skills and plant knowledge (n = 450)

	Plants knowledge	School	Maths	Writing
Schooling	−0.10			
Math	−0.17***	0.70***		
Writing	−0.12**	0.66***	0.76***	
Spanish	−0.08	0.46***	0.51***	0.56***

Notes: *, ** and *** significant at the 10 per cent, 5 per cent and 1 per cent level. Probability adjusts significance levels for multiple comparisons using Šidák method.

Table 3. Relation between traditional and modern human capital among Tsimane' adults (16+ years of age) (n = 450): regression results (dependent variable = logarithm of score in test of plants knowledge)

	[1]	[2]	[3]	[4]
Schooling	0.0001 (0.004)	0.008 (0.006)	0.006 (0.007)	0.007 (0.007)
Math		−0.022 (0.011)*	−0.027 (0.011)**	−0.027 (0.011)**
Writing			0.013 (0.020)	0.013 (0.019)
Spanish				−0.0007 (0.020)
R^2	0.50	0.50	0.50	0.50

Notes: Regressions are ordinary least squares with clustering by village and constant (not shown). Standard errors are in parenthesis. Controls not shown include age, sex and a full set of village dummies (n = 13–1 = 12). For definition of variables see Table 1. *, ** and *** significant at the 10 per cent, 5 per cent and 1 per cent level.

Returns to Traditional Knowledge

Table 4 contains the results of regressions to estimate the parameters of expression (1). In column 1, we show the core model, which consists of ordinary least square regressions with the logarithm of BMI as an outcome variable. The results of column 1 suggest that doubling a subject's stock of traditional knowledge is associated with an improvement in body-mass index of 6.30 per cent.

In columns 2 and 3, we add to the first model variables that capture modern human capital. In column 2, we include schooling and in column 3 we add controls for modern human-capital skills. After controlling for the subject's schooling, the association between plant knowledge and body-mass index remains the same (coefficient = 0.063). To explore the returns to traditional knowledge among subjects with and without schooling, we re-estimated column 2 for people without schooling and for people with some schooling. The results (not shown), suggest that traditional knowledge bore no association with body-mass index among subjects with some schooling (coefficient = 0.03, $p < 0.25$) but, was associated with 0.057 ($p < 0.06$) greater body-mass index among subjects without any schooling.

In column 3 we add to the first model variables that capture modern human capital skills. The coefficient of traditional knowledge drops from 0.063 to 0.056 but remains significant ($p < 0.02$). Among modern skills, only maths bore a statistically significant association with body-mass index but in an unexpected direction. A one-point improvement in the maths score was associated with a 1 per cent lower body-mass index ($p < 0.06$). We tested for the statistical significance of all variables related to modern human capital and found that, as a group, they were not significantly associated with body-mass index ($F = 1.42$, $p < 0.28$).

In columns 4–8, we test for a variety of interaction effects. In column 4 we add an interaction term for schooling and traditional knowledge to assess whether the two forms of human capital act as complements or as substitutes in their association with body-mass index. We find that the interaction effect is not significant. After adding a variable for the interaction of the two forms of human capital, the direct effect of traditional knowledge on body-mass index falls slightly from 0.063–0.056 in the core models to 0.043 in model 3 but remains significant ($p < 0.07$). In column 5, we add a term for the interaction between traditional knowledge and maths skills and find that the interaction term is statistically insignificant. The direct effect of traditional knowledge continues to be positive (0.055) and significant ($p < 0.01$).

Since it is possible that traditional knowledge might have a differential effect depending on the gender of the holder of the knowledge, in column 6 we add an interaction term between traditional knowledge and the subject's sex. The results of column 5 suggest no significant interaction effects with gender. The coefficient of traditional knowledge remains essentially unchanged at 0.070 ($p < 0.02$).

In columns 7 and 8, we estimate the returns to traditional knowledge in relation to market openness. To do so, we interact traditional knowledge with monetary income (column 7) and, traditional knowledge with a dummy variable for village proximity to town (column 8). Income includes earnings from wage labour and the sale of goods, plus the value of goods obtained in barter, all measured for the two weeks before the day of the interview. The dummy variable for proximity to town took the value of one if villages were less than three hours walking time from the town of San Borja during the rainy season (December–February) when the survey took place, and zero otherwise. Three hours is the median value for village-to-town walking time during the rainy season. The intuition is that market openness would be associated with monetary income and proximity to towns (Foster and Rosenzweig, 1996). We find that the results were statistically significant. After conditioning for income and for the interaction of income and traditional knowledge, the non-market returns to traditional knowledge remain positive (0.066) and statistically significant ($p < 0.002$) (column 7). After conditioning for distance and for the interaction of a dummy variable for proximity to town with traditional knowledge, the returns to traditional knowledge rose to 0.078 and remained statistically significant ($p < 0.001$). The coefficients of column 8 suggest that doubling the stock of traditional knowledge among subjects living close to market towns was associated with 4.7 per cent higher body-mass index ($0.047 = 0.078–0.031$), whereas a similar increase in traditional knowledge among subjects living farther away from a market town was associated with a larger (7.8%) improvement in body-mass index ($0.078 = 0.078–0$).

In column 9 we added dummy variables for the decade of birth of the subject. We do so to control for cohort effects. Controlling for cohort effects should lower the estimates of the effects of age on traditional knowledge. As in previous models, after controlling for decade of birth, the returns to traditional knowledge decrease to 0.048 but remained statistically significant ($p < 0.05$).

In column 10 we show the results of a model with fixed effects for households. The results shown in column 10 suggest that once we condition for fixed attributes of households, the returns to traditional knowledge drop to 0.043 and become statistically insignificant ($p < 0.22$). The results suggest that the positive and statistically significant non-market returns to traditional knowledge shown in columns 1–9 are likely to stem from the role of omitted household variables.

We did other analyses (not shown). We re-estimated models 4 and 6–8 by adding the maths variable. Recall that maths bore a negative and statistically significant association with traditional knowledge (Table 3) and it bore a negative association with body-mass index (columns 3 and 5, Table 4), so failure to include maths skills would overstate the significance of traditional knowledge. Adding the maths variable lowered the returns to traditional knowledge slightly but did not change the main results of Table 4 (coefficient between 0.043 and 0.069).

It is possible that traditional knowledge might affect other outcomes besides body-mass index. To explore the possibility, we did various regressions (not shown) with two other proxies of short-run nutritional status as dependent variables – summed triceps and subscapular skinfolds (ZSF) and arm muscle area (ZAM). ZSF assesses body fatness, a low score indicating severe and acute energy stress. ZAM provides information about whether subjects experience acute protein malnutrition. When we use the sum of skinfolds as a dependent variable, the returns to traditional knowledge rose to 0.287 ($p = 0.004$). Doubling a subject's stock of traditional knowledge is associated with an increase of 0.287 standard deviation in the sum of skinfolds. The association between traditional knowledge and arm muscle area was statistically insignificant (coefficient = 0.070; $p = 0.69$).

Table 4. Effects of traditional and modern human capital on logarithm of body-mass index (BMI) among Tsimane' adults (16+ years of age). N = 450

Explanatory variables	Core models			Model [2] + interactions					Secular trends	Household fixed effects
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Plants knowledge	0.063**	0.063**	0.056**	0.043*	0.055**	0.070**	0.066***	0.078***	0.048**	0.043
	(0.023)	(0.022)	(0.021)	(0.022)	(0.018)	(0.027)	(0.016)	(0.010)	(0.022)	(0.035)
Schooling		0.002	0.008	−0.023	0.007	0.002	0.001	0.002	0.004	0.002
		(0.003)	(0.004)	(0.017)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Math			−0.010*		−0.016					
			(0.004)		(0.021)					
Writing			−0.009							
			(0.007)							
Spanish			0.005							
			(0.006)							
Male	−0.003	−0.005	−0.0002	−0.004	0.002	−0.040	−0.007	−0.005	−0.005	−0.0002
	(0.012)	(0.013)	(0.013)	(0.013)	(0.013)	(0.094)	(0.013)	(0.013)	(0.013)	(0.012)
Age	0.0002	0.0004	0.0003	0.0004	0.0003	0.0004	0.0002	0.0004	0.0004	0.0005
	(0.0005)	(0.0003)	(0.0004)	(0.0003)	(0.0004)	(0.0003)	(0.0004)	(0.0003)	(0.001)	(0.0006)
Health	0.001	0.001	0.001	0.001	0.001	0.0009	0.002	0.001	0.002	−0.003
	(0.007)	(.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.010)
Work days	0.006*	0.005*	0.006**	0.005*	0.006*	0.005*	0.001	0.005*	0.004	0.002
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.005)
Household size	−0.001	−0.001	−0.002	−0.001	−0.001	−0.001	−0.002	−0.001	−0.004	−0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Interaction of traditional knowledge with:										
Schooling				0.009						
				(0.007)						
Maths					0.001					
					(0.007)					

(*continued*)

Table 4. (*Continued*)

Explanatory variables	Core models			Model [2] + interactions					Secular trends	Household fixed effects
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Sex (male)						−0.016 (0.036)				
Income							−0.058 (0.213)			
Town proximity								−0.031 (0.035)		
Test schooling = traditional knowledge										
F and (p > F)		8.10 (0.014)	5.70 (0.034)	5.57 (0.036)	7.45 (0.018)	6.21 (0.028)	17.59 (0.001)	49.57 (0.001)	4.31 (0.060)	1.32 (0.251)
R2	0.16	0.15	0.17	0.16	0.17	0.15	0.17	0.16	0.19	0.03

Notes: Standard errors are in parenthesis. Regressions are ordinary least squares with clustering by village. Regressions include village dummy variables and constant (not shown). Modern skills include math, writing, and proficiency speaking Spanish. Town proximity is a dummy; 1 if village < 3 hours walking from the village to the town of San Borja during December–February (rainy season) when the survey took place, and zero otherwise. Income = earnings from wage labour, sale of goods and value of goods obtained in barter. Table 1 contains definitions of other variables.
*, ** and *** significant at the 10 per cent, 5 per cent and 1 per cent level.

IV. Discussion and Conclusions

Two main findings deserve discussion. First, the analysis suggests that traditional knowledge bears a positive association with the body-mass index of adults and with two other indicators of short-run nutritional status, summed triceps and subscapular skinfolds. The non-market returns to traditional knowledge are not trivial, and – for the Tsimane' – are higher than the non-market returns to schooling. Doubling the stock of traditional knowledge of an adult was associated with an improvement in body-mass index that ranged from a low of 4.3 per cent (column 4) to a high of 7.8 per cent (column 8), with a median of 6.3 per cent (column 1). At a mean BMI of 23.1 kg/m^2, a 6.3 per cent increase in BMI represents an increase of 1.5 kg/m^2, a substantial increase. The association between traditional human capital and BMI was stronger among subjects without any schooling and among subjects living farther away from market towns. However, the costs associated with such an increase are also likely to be significant: adult human-capital stocks are accumulated over a lifetime and are not likely to increase significantly in the short run.

Why would traditional knowledge of wild plants be related to higher BMI? The tool we used to measure traditional knowledge consisted of questions about useful plants. Useful plants in the test included, among others, medicinal and edible plants. Therefore, a plausible explanation for the association between traditional knowledge and BMI relates to the effectiveness of medicinal plants and the nutritious value of wild, edible plants. Subjects with higher knowledge of medicinal and edible plants would have higher BMI because they can use the knowledge to cure themselves and to protect their consumption in times of shocks. If the finding proves true, it has some important implications for the health of rural and indigenous populations.

The finding, however, needs to be taken with caution. It must be recalled that we found that the non-market returns to traditional knowledge weakened and became statistically insignificant after controlling for fixed effects of households. The finding suggests that biases from failure to control for various types of unobserved fixed attributes of households and subjects drive some of the results. Households might have adults who know about plants and traditional health practices that improve nutritional status. The presence of such adults might be positively associated with the level of a subject's traditional knowledge of plants and with the subject's body-mass index.

The second finding that deserves discussion is the relation between traditional knowledge and schooling. The analysis presented here suggests that schooling does not necessarily undermine the accumulation of traditional knowledge. Out of four forms of modern human capital measured, only one – maths skills – correlated with less traditional knowledge. Schooling was not significantly associated with traditional knowledge of plants in any of the regressions. Furthermore, when we add an interaction term for schooling and traditional knowledge in the regression model to assess whether the two forms of human capital act as complements or as substitutes in their association with body-mass index, we find that the interaction effect is insignificant. Even when we add an interaction term for maths, the only modern skill bearing a negative association with traditional knowledge, the non-market returns to traditional knowledge remain statistically significant. The finding suggests that modern and traditional human capital operate independently of each other in their association with body-mass index. The finding has important implications for the design of school curricula for indigenous people. If modern and traditional human capital are not substitutes, then it should be possible to include the two forms of knowledge in school curricula, so that those two forms of knowledge act synergistically to improve nutritional status.

We conclude with two suggestions for future research on the non-market returns to traditional knowledge. First, future studies on the non-market returns of traditional knowledge should use better proxies for measuring traditional knowledge. The variable we used included knowledge of many types of useful plants – not just medicinal and edible plants. Random measurement error of the variable for traditional knowledge might produce an attenuation bias. Potentially improved ways of measuring the variable include tests with only medicinal and edible plants, and tests about the ability to use the knowledge reported. Second, researchers studying the non-market returns to traditional knowledge should find a strategy to overcome biases from the potential endogeneity of traditional knowledge. For instance, subjects with more drive might take more care of their nutritional status and make greater investments to acquire the type of human capital that has higher effects on nutrition. Failure to condition for these types of omitted variables might bias the estimate of the returns to traditional knowledge.

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