BMI, Income, and Social Capital in a Native Amazonian Society: Interaction Between Relative and Community Variables

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ABSTRACT Researchers have shown interest in the relation between (a) social capital and individual income and (b) the individual health of people of industrial nations. The socioeconomic complexity of industrial nations makes it difficult to arrive at firm conclusions. We circumvent the obstacle by using data from a small-scale rural society of foragers-farmers in the Bolivian Amazon (Tsimane’). We examine the interactions between the outcome (BMI) and relative income, relative social capital, village income, and village social capital. We test three hypotheses: people in villages with more social capital should have higher BMI, the positive association between social capital and BMI will be more marked among the less well-off, and better-off people who display generosity will have higher BMI than better-off people who do not. On the methodological side we show the importance of: focusing on relative measures of income and social capital, estimating interaction between community and relative measures of income and social capital, and showing results through contour plots that summarize the relation between BMI and pairs of explanatory variables. On the substantive side we find evidence that village social capital and village income complement each other and are associated with higher BMI, the rich who are stingy have lower BMI than the rich who display generosity, and increase in village income might reduce individual incentives to invest in social capital. We explore interactions between explanatory variables and their influence on BMI, and end by recommending the use of an experimental research design to obtain unbiased estimates of causal effects. Am. J. Hum. Biol. 19:459–474, 2007.

Recent years have seen a sally of studies of how individual income and community variables, such as social capital—trust, safety nets, and norms of reciprocity that allow people to protect their individual well-being—might influence individual health (Lynch et al., 2003; Subramanian and Kawachi, 2003, 2004). Most such studies have drawn on information from industrial nations and have worked with indices of social capital aggregated over large geographic units, such as states, departments, census tracts, or metropolitan areas (Wagstaff and van Doorslaer, 2000). We know little about the association between social capital and individual health in small-scale rural societies (Flegg, 1982; Subramanian et al., 2003) and about how relative income and relative social capital over smaller geographical units, such as a village, might interact with each other to shape individual health (Subramanian and Kawachi, 2003, 2004).

Filling the gap matters for at least two reasons. First, the countryside of the developing world contains most of the world’s poor. There, people live in face-to-face small rural villages. In fact, for most of human history people have lived in such villages, so knowing about how social capital and income interact in such settings to affect individual health can tell us something not only about a large share of the world’s poor but also about nearly all humans for most of history.
today's population, particularly the poor, but also about a broad swath of human history.

The past stress on either community or on individual resources has occluded understanding of how relative measures of income or social capital might influence health (Subramanian and Kawachi, 2004; Wagstaff and van Doorslaer, 2000). It might not be the social capital of the community or the income of the person that hews individual health, but how far the person deviates from the community norm that matters most for individual health. This would apply if a person's health reflects how they feel after they compare themselves to the relevant reference group. It might not be the direct effect of relative income or of relative social capital that influences individual health, but how the two relative measures interact with each other and with community measures of income and social capital that mold individual health.

A hurdle in our understanding of how community and individual resources influence individual health stems from reliance on information from observational rather than experimental studies. As a result, researchers have only been able to detect relations using statistical techniques, and have been limited to interpreting the coincidences found.

Given the limitations of observational studies, one can try to control for suspected confounders whose values one measured (or one knows) and for the complexity of the world by reflecting them in the statistical model. Part of our goal is to avoid drawing flawed inferences from oversimplified models (Deaton, 2001; Deaton and Paxson, 1999). We cannot adjust for confounders whose value we did not or could not measure, such as the nutritional intake or the amount of physical exercise of individuals, but we adjust for complications we suspect might color results and for which we have information—namely non-linearity and interactions between explanatory variables.

In this article we contribute to the growing literature on how relative and community measures of social capital and income interact to influence individual health. We do so by drawing on information from a society of hunters, gatherers, and farmers in the Bolivian Amazon—the Tsimane'. The Tsimane' are in the early stages of continual exposure to Westerners and to the market economy. With a relatively stable society and economy until now, the Tsimane' live in villages of about 24 households related by ties of blood and marriage. Their settlement pattern makes it ideal to assess how relative income and relative social capital entwine to influence individual health. A novel aspect of the study is our explicit attention to interactions between income and social capital; we consider each of the two variables at two levels of hierarchy: community level and individual level. We express individual-level variables in relative terms; that is, we compare individual households with the situation specific to a whole village. We use body-mass index (BMI = weight in kilograms/standing physical stature in meters squared) as an outcome variable because BMI is a reliable anthropometric indicator for the short-run nutritional status of a person.

**DEBATE AND HYPOTHESES**

In recent years researchers have argued that in industrial nations social capital protects individual health because it deflects some of the harmful effects that income inequality presumably exerts on individual health (Deaton, 2003; Kawachi, 2000; Lynch et al., 2003, 2004a,b; Subramanian and Kawachi, 2003, 2004; Wilkinson, 1992, 1996). Social epidemiologists have argued that income inequality erodes social capital (Egolf et al., 1992; Kawachi and Kennedy, 1997; Kawachi et al., 1997, 1999; Wilkinson, 1997a). The growth of income inequality and the breakdown of social capital, they go on to point out, increases jealousy, envy, stress, and behaviors related to stress, such as smoking and drinking, all of which hurt self-perceived and objective individual health (Kawachi and Kennedy, 1999, 2002; Macinko and Starfield, 2001; Wilkinson, 1996, 1997b).

The breakdown of social capital also abrades health by increasing cultural dissonance, the gap between shared cultural norms and people's objective socioeconomic status. Anthropologists have found that cultural dissonance, stress, and objective indicators of health, such as blood pressure, move in unison (Dressler, 2004; Dressler and Bindon, 2000; Gravlee and Dressler, 2005; McDade, 2002; McDade et al., 2000). In recent work, Dressler, McDade, and Gravlee use cultural consensus and status incongruity models to show that people in Brazil, Samoa, and the USA (including Puerto Rico) who diverge from cultural norms of health, sociability, and status suffer from worse objective health (e.g., blood pressure) than people closer to the cultural norm. This promising line of research sug-
suggests that divergence from norms shared by a group might hurt individual health.

Pitted against the view that income inequality and the breakdown of community social capital hurt individual health, one finds a second view that emphasizes the cushioning role of individual or community income on individual health that works independent of community income inequality or of community social capital (Duncan, 1996; LeClere and Soobader, 2000; Mellar and Milyo, 2001a,b). Results of studies from developing nations suggest that individual income protects individual adult and child health (Case, 2004; Deaton, 2003; Duncan, 1996; Wagstaff and van Doorslaer, 2000).

Of course both, (a) the income inequality and the social capital of a community and (b) the income of the person and the income level of a community likely interact to affect individual health, so the apt question may not be which of the two dominates. Rather, one should examine the strength of the association between individual health and (a)-(b) and the nature of the links.

We build on these strands of prior research, but move on to fill two gaps. Few of the studies just reviewed examine the effect of relative income or relative social capital on health. The works of Gravlee, McDade, and Dressler just cited, and some of the earlier work on social capital and health, such as the Whitehall study among civil servants in the United Kingdom (Marmot et al., 1987), all found that relative measures—of occupations, of social status, of aspirations—mattered more than absolute measures of the same variables in shaping health. Because they do not examine social capital and because they do not explicitly test for interaction effects between different relative measures, prior findings do not speak directly to our concern, but they point to the importance of examining how far individuals deviate from central tendencies to obtain a fuller understanding of individual health.

The second gap we try to fill has to do with individual incentives to invest in social capital (Glaeser et al., 2002). If social capital confers health advantages and people use it to deflect risk and gain economic assistance, then we need to understand how social capital got there. That is, we need a theory to explain intra-cultural variation in social capital, which leads one to ask why some people might find it more beneficial to invest in social capital than others. Studies from evolutionary theory and ethnographies allow one to derive, deductively, possible explanations and hypotheses about intra-cultural variation in social capital.

Researchers drawing on evolutionary theory (Boyd and Richerson, 1985; Cavalli-Sforza and Feldman, 1981; Henrich and Boyd, 1998; Ridley, 1996) have examined and compared the role of genes and culture in shaping cooperation, the kernel of social capital, and have found that repeated interactions among people in small groups (typically <150) is more likely to generate cooperation, but only toward people who already cooperate. Repeated interactions with the same people allow altruism to emerge. The hurdle with this line of thinking is that it cannot explain intra-cultural variation in cooperation.

We argue that the better-off in a community are more likely to display magnanimity than people who are less well-off. As anthropologists and economists have shown, in small-scale rural societies people invest in social capital to deflect envy, mistrust, witchcraft, and gossip from others (Abraham and Plat-teau, 2001). Witchcraft kills, so the fear of envy, mistrust, and gossip could nettle the haves, and produce direct effects on health. People give gifts and offer help to avoid envy, mistrust, and gossip, and, in so doing, inadvertently, help strengthen the social bonds of the group. Since the better-off are in a better position to display generosity, they do so prudentially to avoid the wrath of those who are less well-off.

Indeed, the cross-cultural ethnographic record suggests that in small-scale societies, prudential generosity often originates from the better-off when the better-off accumulate surplus. An orthodox, textbook reading of the potlach of the Northwest coast, the cargo system of peasant communities in Mesoamerica, and the sharing of meat among native Amazonians (Hill, 2002) would see them as a form of private redistribution from the better-off to the worse-off when economic inequalities in the group expand. The better-off in the group invest in social capital by giving away part of their riches to those at the bottom (or the unlucky) to reduce the stresses that go with economic inequalities. The question one naturally asks is whether villagers push the better-off to display generosity, who reap no private benefits from their generosity, or whether the better-off use generosity as a ruse to indebt receivers. If givers receive net private benefits from their giving because they get
invited food in repayment more often than the better-off who are stingy, then the better-off who are also generous should have higher BMI than the better-off who refrain from sharing their resources.

The literature just reviewed points to at least three hypotheses that we test in the balance of the article.

**Hypothesis 1.** If village social capital protects individual BMI, then, after conditioning for village income, people in villages with more social capital should have higher BMI than people in villages with less social capital.

**Hypothesis 2.** If village social capital protects individual BMI, then people at the bottom of the income distribution in villages with more social capital should have higher BMI than people at the bottom of the income distribution in villages with less social capital.

**Hypothesis 3.** If social capital confers health advantages to the person, then those at the top of the income distribution should invest more in social capital. Facing fewer resource constraints, those at the higher end of the income distribution will find it more advantageous to be generous than those at the bottom of the income distribution, and will see their efforts rewarded with higher BMI. The better-off and generous should have higher BMI than the better-off who are stingy.

**THE SETTING AND THE PEOPLE**

The Tsimane’ are linked with the regional and with the national economy through the sale of forest goods and rice, the principal farm crop (Vadez et al., 2004). They sell those goods to merchants who come to the Tsimane’ territory, but they also take those goods to nearby towns to sell. They sell timber to logging firms and work as unskilled laborers for cattle ranchers, logging firms, and for colonist farmers who have moved into or next to the territory of the Tsimane’. Young men earn monetary income by working for logging firms, cattle ranchers, and colonist farmers, whereas women and adult men earn income by selling farm and forest products. A strong covariate of the level of monetary earnings, a rough proxy for socioeconomic status, has to do with fluency speaking Spanish, Bolivia’s national language. The relation holds even after controlling for schooling, age, sex, and other attributes of the person.

Despite contact with Westerners, the Tsimane’ have low income and remain economically self-sufficient. Mean annual personal income from cash earnings and from the imputed value of farm and forest consumption is US$332, a third of the average income in Bolivia ($US980/person), one of the poorest nations in Latin America. Goods bought in the market accounted for only 2.68% of the total value of household consumption.

Like other native Amazonians, the Tsimane’ practice preferential cross-cousin marriage, meaning that a man weds his mother’s brother’s daughter. Residence is matrilocal shortly after marriage, followed by neolocal residence. Polygynous in the past, the Tsimane’ today mostly practice monogamy and live in nuclear households in small villages that contain about 24 households each.

Households visit each other often within and across villages to enjoy each other’s company, or to exchange goods and information (Ellis, 1996). An earlier survey in 2000 with 509 participants in 58 villages showed that only 10% of adults lived in their village of birth, hinting at the prevalence of migration between villages.

Like other native Amazonian populations, the Tsimane’ routinely share the ubiquitous home-brewed drink called chicha, typically made from manioc, but also from plantains or maize. Any Tsimane’ can walk into a household serving chicha and expect to be served. In the smaller villages, people cook in open courtyards and shout when the meal is ready so all can join in communal eating. Successful hunters share game with others. In an earlier (1999–2000) study over five consecutive quarters done in two villages, we found that 11% of all goods entering households from morning until dusk on days chosen at random came as gifts or as transfers from friends or relatives; those goods accounted for 6.70% of the total value of household consumption. Tsimane’ work in groups to set up traps to fish with plant poison; people in the fishing expedition take the fish they catch with their own nets (Pérez, 2001). In the 1999–2000 panel study, we found that group fishing accounted for about a quarter of all fishing events. Communal work prevails in the construction and in the maintenance of schools, in some hunting expeditions, in the cleaning of public places, and in preparations for village festivities. In the more isolated villages, people work together in the more arduous tasks, such as felling large trees at the start of the farming cycle, but only for subsistence crops, not for cash crops.
As in other native Amazonian societies, among the Tsimane’ gift giving, communal labor, and help in work permeate daily interactions. Information from the two waves of panel data used for this article suggest that the share of households that made gifts during the week before the day of the interview were as follows: 71% of household gave home-brewed drinks, 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 4.45% of households did not make either any gifts or offer any help. The figures suggest that Tsimane’ practice extensive reciprocity.

But offsetting public expressions of generosity one also finds evidence of accumulation of material possessions and economic inequality. The presence or lure of public schools, the territorial circumscription from the expansion into the Tsimane’ territory of loggers, cattle ranchers, and colonist farmers (Godoy et al., 1998), and the debt peonage into which some Tsimane’ have fallen with outside merchants—create incentives to move less and to accumulate more material possessions. With a more sedentary lifestyle the possibilities for accumulating wealth rise. 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 by the village or by groups larger than the household. People in villages closer to towns build walls to enclose their homes and even put fences around their courtyards. To guard their material possessions, some Tsimane’ put locks on their doors when they leave the village. Even in meals one finds evidence of stinginess. Although one finds that communal meals are common in smaller villages, with people from the same household or hamlet literally eating from a common pot, people do not go out of their way to invite others to share in their meals. Tsimane’ often turn their backs to others when they eat (Ellis, 1996), and people in the more modern villages or in villages more exposed to Westerners complain that neighbors do not share meat and so violate expectations of proper social norms. The practice of eating from a common pot gives way to the practice of eating from individual dishes. In a panel study over five consecutive quarters done in 1999–2000 we probed how households had coped with unforeseen income shocks (e.g., crop loss), and found that only 5% of the sample received help from kin or neighbors after a misfortune. Though reciprocity and gift giving permeate Tsimane’ society, prudential generosity does not gain salience after an individual suffers personal misfortune.

MATERIALS AND METHODS

Information for this article comes from a bio-cultural longitudinal study (1999-present) with the Tsimane’. Details of the study can be found at: http://people.brandeis.edu/~rgodoy/overview/pgs/overview.html. For the article, we draw on data from two annual surveys collected from the same participants during February-April of 2001 and 2002. The baseline survey of 2001 contained 37 villages and 387 households. Villages varied in distance to the closest market town. In each village we selected at random an average of 10 households for the survey. In each household, we selected at random between the female or the male head of the household to answer survey questions and to take anthropometric measures. For questions about the entire household, we allowed other people in the household to contribute to the answer of the household head answering the questions.

Elsewhere we have described the methods used to collect the information presented here (Godoy et al., 2005a), so for brevity we limit the discussion of this section to the methods used to collect information on BMI, income, and social capital.

We begin with a brief discussion to clarify how the measure of relative and community income and social capital relate to each other in the analysis and to the hypotheses. In Table 1 we present income as columns and social capital as rows. We split columns and rows into two levels—relative and village—and use italics for the name of variables. *Individual income* refers to the income of the person. *Village income* refers to the average *individual income* of the village. *Relative income* refers to *individual income* relative to the village norm, as described later. The same logic applies to the
three measures of social capital. Table 1 shows that cell A, B, and C bear on hypotheses 1, 2, and 3. Figures 1, 2, and 3 show the results of the test of hypotheses 1, 2, and 3.

**Outcome variable**

We use BMI for household heads or people over the age of 16. By the time Tsimane’ reach 16 years of age, they typically begin to prepare their own farm plots and are considered adults. Sixteen is also the age at which Tsimane’ set up their own households.

BMI provides a general and widely used omnibus-type measure of under nutrition and risk of obesity. We used 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 millimeters using a portable stadiometer or a plastic tape and body weight to the nearest 0.2 kg using a standing scale. Mean and median BMI for male heads of households were 23.30 and 23.17 (SD = 2.31; Kurtosis = 5.31; min = 15.09; max = 32.93). Mean and median BMI for female heads of households were 22.88 and 22.71 (SD = 2.75; Kurtosis = 3.43; min = 14.93; max = 31.23). These mean and median values are in the middle of normal adult BMI range of 18.5–24.9 kg/m², as recognized by the National Institute of Health (NIH, 1998). We tested and found not significant relation between BMI and age or between BMI and household size.

The limitations of BMI as a measure of nutritional health have been widely discussed in the human biology and nutritional sciences literature (Garn et al., 1986a,b; Norgan and Jones, 1995; Prentice and Jebb, 2001). Because BMI does not measure body composition, it serves as a proxy for obesity risks rather than a direct measure. In addition, a number of studies have shown BMI to be sensitive to variation in frame size and body proportions. For populations with more linear body builds, BMI tends to underestimate nutritional status (Deurenberg-Yap et al., 2000; Norgan, 1994a,b). In contrast, among populations with larger trunks and shorter limb lengths (e.g., arctic populations) BMI tends to overestimate nutritional status and obesity risks (Leonard et al., 2002; Shephard and Rode, 1996). Despite its limitations, BMI has been the most broadly accepted single anthropometric measure of energy and nutritional status (Shetty and James, 1994).

Tsimane’ adults obtain adequate amounts of energy and protein from their staples, and generally do not show acute nutritional stress. Nevertheless, the Tsimane’ diet may not be adequate to fulfill the high nutrient demands of young children. Indeed, many of the staple foods (e.g., manioc, plantains) may not be sufficiently dense in energy, protein, or in key micronutrients to sustain the rapid growth rates that typically characterize infancy and early childhood. Low dietary quality combined with a high infection rate contribute to the high incidence of stunting in physical growth among the Tsimane’ (Foster et al., 2005; Godoy et al., 2005b,c; McDade et al., 2005; Tanner, 2005). We found that 38% of household heads in our sample were growth stunted. Stunting was assessed relative to the National Center for Health Statistics standards (Hamill et al., 1979).

The rate of obesity is low, particularly in comparison with populations in the Western world (Flegal et al., 1998; Frisancho, 1990; Gray and Bray, 1991). Recent health recommendations advocating the use of BMI say that a healthy BMI ranges from 18.5 to 24.9 (National Institute of Health, 1998; Shetty and James, 1994). The mean and median BMI for Tsimane’ male and female heads of households fell in that range. The BMI cut-off for obesity is 30 (Shetty and James, 1994). Only six male (1.55% of sample) and one female (0.58% of sample) had a BMI over 30. Even using a more conservative threshold for obesity (BMI ≥ 27.5) (Must et al., 1991), results in only 4.7% of the male and 7.0% of the female observations being categorized as obese.

**Explanatory variables: Income and social capital**

The measure of income in small-scale rural societies poses at least two challenges for em-
behavior is a more objective and reliable measure of social capital than norms (Glaeser et al., 2000). We highlight two forms of social capital—gift giving and communal work or labor help given to other households—because they represent the main expressions of generosity in small-scale rural societies (Godoy, 2001; Hill, 2002).

The variable social capital captures the total number of times during the 7 days before the day of the interview that households did the following: (i) gave gifts of home-fermented drinks, cooked food, maize, rice, manioc, fish, meat, seeds, or medicines, and (ii) offered help hunting, fishing, farming, running errands, and doing other work. We computed the average level of social capital in the household by dividing the total episodes of generosity of the household by the number of people in the household; we call the variable individual social capital.

From the two variables—individual income and individual social capital—we computed the variables relative income and relative social capital. Relative income stands for the logarithm of the ratio between individual income and the village geometric mean income (village income). Relative social capital stands for the difference between individual social capital and the village-level (arithmetic) average social capital (excluding the household supplying the information) (village social capital).

For the visual analysis we present contour plots akin to topographical maps, with two covariates plotted along the X (analogous to longitude) and Y (analogous to latitude) axes and with contours expressing the third dimension, i.e., the level of individual BMI as a dependent variable (as a height of the BMI surface above the XY plane), while holding the two explanatory variables at their averages. For ease of exposition, we make references to the cardinal points (e.g., north-west; south) when discussing positions in the figures.

**STATISTICAL MODEL**

We work with a model linear in parameters having village-specific random effects, other effects being fixed. Therefore, we deal with the linear mixed model (LME) (Davidian and Giltinan, 1995; Pinheiro and Bates, 2000). The random effect adds an extra level of variability (besides the residual variability from usual regression models) useful for handling heterogeneity among villages and for the tendency of measures taken in the same village of...
being more alike or correlated than those taken in different villages. The model is expressed in Eq. (1):

$$BM_{ij} = \beta_0 + b_i + \beta_1(RI)_{ij} + \beta_2(RS)_{ij} + \beta_3(RI)_{ij}^2 + \beta_4(RS)_{ij}^2 + \beta_5(VI)_{ij} + \beta_6(VS)_{ij} + \beta_7(VS)_{ij}^2 + \beta_8(VI)_{ij}^2 + \beta_9(VS)_{ij} + \beta_{10}(VJ)_{ij} + \epsilon_{ij}$$

where:

- $BM_{ij}$ is the BMI value of the $j$-th respondent in the $i$-th village (single representative of a household).
- $RI_{ij}$ is the relative income value of the $j$-th respondent in the $i$-th village.
- $VI_{ij}$ is the village income value of the $i$-th village.
- $RS_{ij}$ is the relative social capital value of the $j$-th respondent in the $i$-th village.
- $VS_{ij}$ is the village social capital value of the $i$-th village.
- $\beta_0, \beta_1, \ldots, \beta_{12}$ fixed effects.
- $b_i \sim N(0, \sigma_e^2)$ village-specific effects (random intercepts).
- $\epsilon_{ij} \sim N(0, \sigma^2)$ random (observational/measurement) errors.

Apart from the overall intercept and village-specific intercepts (random coefficients $\beta_0 + b_i$), we have here effects of:

(i). village-level income ($VI$) as a “typical” or reference value of income for all inhabitants of the particular village,
(ii). village-level social capital ($VS$) as a “typical” or reference value of social capital for all inhabitants of the particular village,
(iii). individual (household)-level relative income ($RI$) as a comparison of individual (household) income with relevant $VI$,
(iv). individual (household)-level relative social capital ($RS$) as a comparison of individual (household) social capital with relevant $VS$.

Besides the simple linear effects $VI$, $VS$, $RI$, $RS$, we include their squares to capture suggestions of nonlinearity in the data. Moreover, we introduce interactions (cross-product terms) to check whether income ($I$) and social capital ($S$) combine additively or whether they interact to potentiate effects. Since we discriminate between the effects of $S$ and $I$ at the two levels (population and individual), we can discriminate between local and population-level interactions ($RI=RS$ and $VI=VS$). After fitting this quadratic surface, we explore and present it on contour plots providing three-dimensional views of BMI as a modeled surface and various pairs of explanatory variables (out of the total of four: $VS, RS, VI, RI$).

To test whether the interaction is present among relative and absolute measures of social capital and income, we compute a likelihood ratio test comparing model Eq. (1) and a null or restricted model Eq. (2), shown next:

$$BM_{ij} = \beta_0 + \beta_1(RI)_{ij} + \beta_2(RS)_{ij} + \beta_3(VI)_{ij} + \beta_4(VS)_{ij} + \beta_5(VSI)_{ij} + \epsilon_{ij}$$

The test of models (1) versus (2) is a test of the null hypothesis of no interaction among the explanatory variables considered. Its $P$-value is 0.038, hence it is significant at the conventional 5% level.

MAIN RESULTS

Hypothesis 1. If village social capital protects individual BMI, then, after conditioning for village income, people in villages with more social capital should have higher BMI than people in villages with less social capital.

Figure 1 suggests that, after controlling for village income (i.e., holding it constant), people in villages with more village social capital have higher BMI than people in villages with less village social capital (movement from north to south-east). Village social capital has a stronger (and monotonous) association with BMI at low levels of village income than at high levels of village income. For example, among the poorest villages (west), increases in village social capital (movement from the south-west to the north-west) are associated with a steady improvement in BMI. Among better-off villages (east) increases in village social capital (movement from the south-east to the north-east) are also associated with an improvement in BMI, but the rate of improvement or slope is lower than among poorer villages; for the better-off villages, the change appears to be even slightly non-monotonous. In sum, we find support for hypothesis 1 that conditioning on village income, an improve-
ment in *village social capital* bears a positive association with individual BMI, but importantly, the association is *modified* by the *village income* level.

Besides supporting hypothesis 1, Figure 1 also shows how the relation between (a) individual BMI and (b) village income and social capital is best captured through interaction effects of explanatory variables rather than through the more traditional additive (social capital + income) modeling approach.

**Hypothesis 2.** If village social capital protects individual BMI, then people at the bottom of the income distribution in villages with more social capital should have higher BMI than people at the bottom of the income distribution in villages with less social capital.

In Figure 2 we show the relation between *village social capital* and *relative income*. If we hold constant *relative income*, then an improvement in *village social capital* is associated with higher individual BMI, but mainly among the poor. Figure 2 shows that a poor person in a village without much *village social capital* (south-west) has a lower BMI than a poor person in a village with more *village social capital* (e.g., north-west). If, instead, we focus on the people at the upper end of the income distribution we see that individual BMI also rises as we move from villages with low *village social capital* (south-east) to villages with more *village social capital* (north), but the magnitude of the change in BMI is lower than among the poor. Among people in the middle of the income distribution, we find a more complex relation. We observe an increase in BMI in villages with low *village social capital* (middle of the south to south-east line) but in villages with high *village social capital* (north) the magnitude of change in individual BMI becomes negligible.

The findings lends credence to the idea that in small-scale rural societies, *village social capital* acts as a compensatory mechanism or safety net against the limitations imposed by low income (Morduch, 1995). Compensation occurs where it is most needed—among the poor—and wanes among those at the top of the income distribution.

In the introduction we noted that interactions between explanatory variables could
produce misleading and mutually contradictory results if one simply used an additive model. Figure 2 supports the observation. For instance, a study limited to the south-east region of the plot would produce the impression of insubstantial links between \textit{relative income} or \textit{village social capital} and BMI. The region is relatively flat. Nevertheless, a study in the north-west corner would show sharper links between BMI and \textit{village social capital} and \textit{relative income}.

In sum, we find that \textit{village social capital} and \textit{relative income} intertwine and bear associations with BMI. In rural, small-scale, face-to-face societies without formal mechanisms of insurance, people invest in others through various expressions of generosity to shield themselves against adversity when misfortunes strike (Morduch, 1995). They also give gifts and offer help to avoid the animus of others. Gifts and help, or what we have here termed \textit{village social capital}, form the cultural glue that binds small-scale rural societies (Abraham and Platteau, 2001). This would explain why \textit{village social capital} compensates against the negative effects of low income.

\textit{Hypothesis 3.} If social capital confers health advantages to the giving person, then those at the top of the income distribution should invest more in social capital. Facing fewer resource constraints, those at the higher end of the income distribution will find it more advantageous to be generous than those at the bottom of the income distribution, and will see their efforts rewarded with higher BMI. The better-off and generous should have higher BMI than the better-off who are stingy.

Figure 3 shows the relation between BMI and the interaction of \textit{relative social capital} and \textit{relative income}. If we focus on people at the upper end of the income distribution, we see that as their \textit{relative social capital} rises (movement from south-east to north-east)—as they give more gifts and as they help others more, or as they rise in generosity relative to the village norm—we observe higher individual BMI. People who are well-off but stingy—those at the south-east corner of the map—have the lowest BMI, whereas people who are better-off and generous (north) have the largest BMI.
So far we have seen that the better off who display more social capital than the village norm of social capital have better BMI than better-off but stingy persons. Now we examine the relation between: (a) individual BMI and the interaction of (b) village income and relative social capital. We want to examine whether the generous have higher BMI across different levels of village income. The analysis corresponds to cell D in Table 1. The analysis matters because it allows one to assess whether economic development or a rise in average village income might abrade social capital, thereby perhaps harming BMI.

Figure 4 shows the complexity of the interplay between relative social capital and village income in their influence on BMI. We are dealing with a saddle-point of the BMI surface here. Figure 4 suggests that individual investments in social capital (e.g., more expressions of generosity) are associated with higher BMI in villages with low village income, with lower BMI in villages with high village income. For the more generous people one can see in Figure 4 that as village income rises, BMI declines (movement from south-east to north-east), and the opposite occurs among the misers (movement from south-west to west). The pattern tends to flip around for above-average villages: for more generous people, BMI declines in the better-off villages (movement from east to north-east) and for misers it increases (movement from west to northwest), but that is where there are not many data points available.

EXTENSIONS AND PATHS

We next explore why social capital might be associated with higher BMI and consider two paths for which we have information: consumption smoothing and mirth. To do so, we draw on a survey of 13 villages done later, in 2004, in which we asked adults or people over the age of 16 to list all mishaps they had experienced during the month before the day of the interview, and—for each mishap—to tell us how they had coped with the mishap. If social capital gets activated in a prudential way to help people cope with misfortunes, then we should see people reporting reliance on friends or kin outside the household to cope with adverse events. In Table 2 we tabulate the answers people gave us about the way they had coped with mishaps.

Contrary to what one might have expected, social capital in the form of help from family
or friends did not gain prominence after a misfortune. Only about 20% of people relied on social safety nets (and only 11% would correspond to out-of-household social safety nets that are accounted for by social capital as defined and used in our model here). The results are not unique to the study of 2004; they also echo the results from an earlier study with the same ethnic group over five consecutive quarters done during 1999–2000 in two villages with a total of about 60 households. In the study of 1999–2000 we found that 82.08% of people experiencing a negative shock coped with the misfortune on their own, without help from kith or kin.

Another possible path centers on the effect of social capital on mirth and, through mirth, on BMI. Using the information from the survey of 2004, we explore whether social capital might bear an association with subjective well-being. We asked people to list up to four events that had made them happy during the 7 days before the day of the interview. In Table 3 we present the results of the tabulation. Close to a quarter (24.27%) of the answers about what made them happy centered on the quality of their social relations, so we find some evidence that social capital might be perceived as contributing to subjective well-being, but how about the link between subjective well-being and BMI?

In still another study done during 2003–2004 over five consecutive quarters with 329 women and 350 Tsimane' men over 16 years of age in the same 13 villages as the study of 2004, we found that people who displayed mirth through smiles, laughter, or both during

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**TABLE 2. Mechanisms of coping with misfortunes among Tsimane’ adults (16+ years of age) in the Bolivian Amazon, 2004**

<table>
<thead>
<tr>
<th>Mechanism to cope with shock</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did nothing</td>
<td>96</td>
<td>46.83</td>
</tr>
<tr>
<td>Social capital</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family</td>
<td>17</td>
<td>8.29</td>
</tr>
<tr>
<td>Outside family</td>
<td>23</td>
<td>11.22</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>19.51</td>
</tr>
<tr>
<td>Solved it by myself</td>
<td>24</td>
<td>11.71</td>
</tr>
<tr>
<td>Helped by missionaries</td>
<td>9</td>
<td>4.39</td>
</tr>
<tr>
<td>Helped by tribal government</td>
<td>8</td>
<td>3.90</td>
</tr>
<tr>
<td>Asked for credit</td>
<td>4</td>
<td>1.95</td>
</tr>
<tr>
<td>Worked</td>
<td>4</td>
<td>1.95</td>
</tr>
<tr>
<td>Sold animals</td>
<td>2</td>
<td>0.98</td>
</tr>
<tr>
<td>Sold rice</td>
<td>1</td>
<td>0.49</td>
</tr>
<tr>
<td>Other</td>
<td>17</td>
<td>8.29</td>
</tr>
<tr>
<td>Total</td>
<td>205</td>
<td>100.00</td>
</tr>
</tbody>
</table>

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![Fig. 4. Relation between BMI, village income, and relative social capital. (Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.)](image-url)
interviews lasting 1–2 h had 2.4–5.4% higher BMI than somber people who neither smiled nor laughed (Godoy et al., 2005b). We also find that sadness is associated with lower growth rates in BMI and that melancholy might hurt nutritional status through social capital. We find that melancholy at baseline or during the first quarter of the panel study (2003–2004) was associated with fewer expressions of generosity over the subsequent four quarters. Sad people at baseline or during the first quarter engaged in one less episode of communal labor or helping behavior toward other villagers at follow up during the fifth quarter (t = 1.79, P < 0.07; mean = 0.31, SD = 0.57). In sum, the evidence suggests that the association between social capital and BMI probably has more to do with subjective well-being than with consumption smoothing. We do not have information on time allocation to assess whether social capital affects BMI through reduced work load. Nor do we have information on net exchanges of goods and services between households to assess how social capital contributes to net food consumption. These two paths, time allocation and exchanges, require attention in future studies.

LINKS TO OTHER FINDINGS FROM THE TSIMANE’

The analysis presented here complements the results of other studies on the links between income, market exposure, social capital, and income inequality that we have done among the Tsimane’. In general, we have found little evidence that market exposure erodes canonical indicators of individual well-being, such as secular trends in adult physical stature or ethnobotanical knowledge (Godoy et al., 2005c, 2006a), but it does seem to be associated with lower investments in social capital, as we found here (Godoy et al., 2006b; Reyes-Garcı´a et al., 2006). We find evidence of spillovers from groups to individual decisions to invest in social capital. We have found weak evidence that village income inequality hurts self-perceived indicators or objective indicators of health even after we condition for a wide range of covariates (Godoy et al., 2005a). Nevertheless, we find that village income inequality is positively associated with more frequent individual expressions of negative emotions, such as anger, fear, and sadness (Godoy et al., 2006c). We have taken these findings as suggestions that village income inequality might increase negative emotions and stress behaviors before harming health. In contrast to the results presented here, all our previous work centered on estimating direct, additive effects, rather than interaction effects between explanatory variables.

STRENGTHS AND LIMITATIONS OF THE ANALYSIS

Strengths of the article include the use of a relatively large sample size of observations done over two consecutive annual surveys, an explicit focus on how relative rather than absolute measures of social capital and income might interact to shape BMI, and the use of contour plots to display the results of the statistical analysis.

Limitations of the article include difficulties of measuring income in a remote rural society where the distinction between work and leisure, production and consumption, and supply and demand is blurred. A second limitation bears on the appropriateness of the concept of social capital in such societies. In industrial societies, researchers equate social capital with acts of generosity and pro-social behavior toward strangers, but in small-scale, rural societies where people in a village are tied by bonds of kinship, acts of generosity toward strangers or people of other households may, in fact, be a type of familism rather than true altruism. A third limitation has to do with the absence of ethnographic examples to illustrate the statistical findings; we had to suppress such examples owing to space limitations. Last, we could not correct for the endogeneity of income or social capital.
CONCLUSION

In this article we have tried to make a methodological and empirical contribution to the understanding of the links between income, social capital, and individual BMI. On the methodological side we have shown the importance of: (a) focusing on individual measures of income and social capital relative to the community norm, (b) estimating interaction effects between community and relative measures of income and social capital, and (c) showing results through contour plots that summarize the relation between BMI and various pairs of explanatory variables.

On the substantive side, we find evidence suggesting that (a) village social capital and village income complement each other in being associated with higher BMI, particularly among those at the bottom of the income distribution, (b) the better-off who display generosity have higher BMI than the better-off who do not display generosity, and (c) village income levels might undermine individual incentives to invest in social capital. In short, relative measures of income and social capital seem to be associated with higher BMI even in a small-scale, face-to-face, rural society.

The idea that social capital is associated with better health in rural settings of developing nations is not unique to this study. In a study of households in KwaZulu-Natal, South Africa, Carter and Maluccio (2003) found that households that participated more in community groups coped better with adverse economic shocks and, so, had children with better height-for-age Z scores. They also found an interaction between individual and community income. A household that suffered a mishap fared worse if it lived in a community experiencing a large mishap.

Standard explanations for why social capital might contribute to better health typically point to the protective effect of social capital in the face of economic misfortunes, as in the study of Carter and Maluccio (2003), or as is in the literature from social epidemiology reviewed earlier. Among the Tsimane we found weak evidence that social capital acts as insurance to protect BMI or that village income inequality hurts anthropometric indices of nutritional status (Godoy et al., 2005a,c). Rather, the protective effect of social capital on BMI probably gets played out through more subtle channels having to do with mirth, absence of sadness, and with a general sense of well-being. Expressions of pro-social behavior in small-scale, rural societies get paid back with gifts and labor services that likely produce net increases in consumption, possible reduced work load, and, in consequence, better nutritional status. Much remains to be known about the paths by which social capital—whether own, relative, or village—influence BMI.

We end with a suggestion for future research. Perhaps the single most important conclusion to emerge from the study centers on the non-linear, complex interactions between: (a) BMI and (b) relative and mean village income and social capital. As noted, observational studies, including ours, make it difficult to detect with precision how individual, relative, and village income and social capital interact to shape BMI. The use of instrumental variables for social capital has been no panacea (Durlauf and Fafchamps, 2006). A novel approach to circumvent the hurdle would center in randomly changing both the level of income and income inequality of communities by, for instance, making income transfer to people selected at random in the bottom half of the income distribution. By varying at random the level of individual income, the income distribution of the community, and the recipient of the transfer, one could assess with more precision how individual and relative income influence social capital and individual health. The simple experiment would go a long way in helping to move the debate toward denouement.

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LITERATURE CITED


