Why no adult stunting penalty or height premium?

Estimates from native Amazonians in Bolivia

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Abstract

Background: Among adults of industrial nations, growth stunting (<-2SD height Z score) correlates with worse indicators of adult well-being (e.g., morbidity, income). But does adult stunting also inflict private costs in traditional rural societies? Adult stunting penalties or height premiums might only emerge when traditional societies modernize.

Aim: Estimate the association between adult stunting and indicators of adult well-being in a traditional society using data from a panel study in progress among the Tsimane', a foraging-farming society of native Amazonians in Bolivia.

Participants and methods: 248 women and 255 men ≥ age 22 measured annually during five consecutive years (2002-2006). Nine outcomes (wealth, monetary income, illness, access to credit, mirth, schooling, math skills, plant knowledge, forest clearance) were regressed separately against a stunting dummy variable and a wide range of control variables.

Results: We found no significant association between adult stunting and any of the indicators of own well-being. Additional analysis showed that stunting bore an association only with poorer mid-arm muscle area.

Conclusion: Height premiums and stunting penalties, though visible and marked after societies modernize, are not common in traditional societies.

Key words: Bolivia, Tsimane', Tsimane' Amazonian Panel Study (TAPS), height premium, stunting penalty

Introduction

A large body of evidence from low-income nations (recently reviewed in three articles of *The Lancet* (Engle et al., 2007; Grantham-McGregor et al., 2007; Walker et al., 2007) documents the pervasiveness of childhood growth stunting – or being two standard deviations (SD) below the median height of a child's peers of the same age and sex in the USA. Childhood growth stunting (hereafter *stunting*) has received much attention in public health because it erodes cognitive abilities and health outcomes during childhood and adulthood (Engle et al., 2007; Fernand and Grantham-McGregor, 2002; Grantham-McGregor et al., 2000; Grantham-McGregor, 1995; Grantham-McGregor et al., 2007; Pollitt et al., 1995; Walker, 2007). Stunted children tend to end up as stunted adults (Liu et al., 2000). Among adults of industrial nations, standing physical stature is positively associated with many indicators of own adult well-being, such as occupation, monetary income, wages, IQ, longevity, and good health (Bogin and Keep, 1999; Case and Paxson, 2006; Komlos, 1994; Pollitt et al., 1995; Steckel and Rose, 2002). Additional evidence of the height premium or the stigma associated with growth faltering comes from the increasing demand for growth hormones among young adults and their parents in industrial nations (Lagrou et al., 2008; Visser-van Balen et al., 2005; Waal and Verhulst, 1996). At least among adults of industrial nations, growth stunting inflicts private costs.

But does adult stunting also impose private costs in contemporary traditional rural societies? If height is associated with health and productivity, then it should be a marker of sexual attractiveness and reproductive success. Previous research on height premiums and stunting penalties has focused almost exclusively on reproductive outcomes and suggests that in traditional societies female height bears a positive association with reproductive success (Pollet and Nettle, 2008) but male height does not correlate well with own fertility or with child survival (Sear, 2006). Outside of reproductive success, the question of whether adult stunting inflicts private costs has barely been broached, at least to our knowledge. In saying this, we are fully cognizant of the literature linking height to a variety of health and socioeconomic indicators of well-being (cited in the previous paragraph) but none to our knowledge explicitly estimating the effects of adult stunting on own adult well-being. The answer to our query of whether adult stunting inflicts penalties in canonical indicators of adult well-being, as it does in industrial societies, is far from obvious, and this is so for at least two linked reasons.

First, most of the research known to us on the consequences of stunting in low-income nations focuses on children rather than on adults, probably because growth stunting in childhood might be irreversible[i], so understanding the dynamics of stunting during the early stages of the life cycle might be more important than understanding its consequences later in life. A related reason for the paucity of research has to do with the turbulent history of the "small-but-healthy" hypothesis. In the early 1980s Seckler (1982) advanced the hypothesis that in many areas of low-income nations, a short or stunted child (but not a wasted or a thin child) might be healthy and as productive as a non-stunted peer (Roos, 2009). He went on to argue that shortness might be an adaptation to mild to moderate malnutrition. The hypothesis generated much criticism (Beaton, 1989; Dasgupta, 1993; Martorell, 1989; Messer, 1986; Panter-Brick, 1998; Pelto and Pelto, 1989; Scheper-Hughes, 1992) in part because of the world-wide evidence that childhood stunting is associated with worse cognitive and health outcomes among children, but the hypothesis and riposte leave unanswered our initial query of whether adult stunting abrades indicators of adult well-being.

Second, it is theoretically possible that in some societies adult stunting will impose no meaningful or obvious private costs on the stunted person. Even in industrial society, the height premium (at least in reproductive success) applies mostly to men (Nettle, 2002). But suppose one lived in a society infested with parasites and devoid of good nutrition and public health, and in which adult height conferred no benefits to the person within the group. It did not make one a better hunter because the bramble and the low-lying branches of the trees made it hard for tall foragers to move with ease and speed in pursuit of game. It did not make one a more efficient employee in the labor market because occupations were low skilled and, more importantly, employers knew the skills of the employees because employer and employee had known each other from childhood onwards, and so the employer did not have to use height as a cue for unobserved employee skills. It did not make one a more attractive mate choice because a taller mate would not necessarily bring in more resources to the household. In short, imagine that adult height conferred no private benefits in the most visible markers of socioeconomic or demographic success. Furthermore, suppose that taller people needed more food and so had to hunt, farm, fish, and work more, and therefore used more natural resources from the local environment. If so, then it is not hard to imagine that a cultural tapestry (and mate preference) might have developed over generations, which essentially turned a blind eye to tallness, both because it conferred no visible advantages to the adult given the specificities of the local ecology and because it imposed short-run social cost on society and on the environment.

Besides filling a gap in the empirical literature on human growth, estimating the association between adult stunting and indicators of adult well-being matters because it contributes to our theoretical and empirical understanding of the causes of child stunting. Orthodox explanations of childhood stunting focus on the *past* or on the *current* environment, including ***(1)*** child attributes (Fernald and Neufeld, 2007; Kalanda et al., 2005; Simondon et al., 1998), ***(2)*** maternal attributes (e.g., conditions *in utero* and before pregnancy) (Adair, 1999; Gray et al., 2008; Kuzawa, 2008), and ***(3)*** household and community socioeconomic and demographic attributes during pregnancy and during the period of child growth (Eckhardt et al., 2005; Kain et al., 2005; Leonard et al., 2000; Martorell and Scrimshaw, 1995). Researchers have elided incorporating the role of parental expectations about the future benefits of adult tallness or the future costs of adult stunting in models of child growth.

The shortcoming is lamentable. One of the simplest cues parents have now to assess the future benefits of redressing growth faltering in their children comes from parents observing the possible penalties of stunting or the height premiums among those adults a parent can observe now. Stunting penalties or height premiums among observed adults now send reasonably accurate information to parents about whether to allocate resources for child growth, particularly in relatively stable socioeconomic environments. Additionally, height premiums or stunting penalties likely play a role in determining the ideal height of reproductive partners. On the other hand, with major structural transformations in the socioeconomic, demographic, and cultural fabric of a traditional society, stunting penalties or height premiums might send noisier signals to parents about how to allocate resources for their children's growth. For example, in a traditional society stunted or very tall individuals may not differ from others in socioeconomic or reproductive attributes and, so, parents might decide from observed adults that it does not pay to invest too much in child growth. This means parents will seek to remedy growth deficits only if they fall well belong the 'normal' growth for the group, rather than continually seeking to maximize the height of their child so they end up well above the mean – and closer to international growth standards. But if society is changing as parents make these decisions, then the cues on which they based those decisions may have been inappropriate. If we are right in this line of thinking, then *another* possible reason for the ubiquity of stunting in rural areas of low-income nations that have yet to experience major structural transformations might have to do with modest adult height premiums and with the modest stunting penalties as *perceived* by parents.

In this article we estimate the association between a wide range of indicators of adult well-being (outcome variables) and stunting among people over 22 years of age in a native Amazonian society of foragers and farmers in the department of Beni, Bolivia (Tsimane') who are in the early stages of continual exposure to the market economy. Among indicators of well-being we selected economic outcomes (e.g., monetary income, wealth, area of forest cleared for agriculture), social outcomes (e.g., ability to borrow in an emergency), health outcomes (e.g., bed-ridden days), psychological outcomes (e.g., propensity to remain somber), and human-capital outcomes (e.g., schooling, math skills, practical ethnobotanical knowledge). We selected a wide range of indicators on purpose to ensure that the private costs of stunting or that the benefits of height are captured over many domains of high visibility and that could act as a cue to parents. Adult stunting probably correlates with unobserved objective indicators of adult health (e.g., blood pressure, stress hormone levels), but we leave those health outcomes aside both because we do not have current data on them and because they are unlikely to act as a signal to parents on how to invest in child growth. For the purpose of this article we define an adult as a person over 22 years of age because Tsimane' stop growing by the early 20s (Godoy et al., 2006a).

Materials and variables

Materials. We use a freshly minted five-year annual panel (2002-2006, inclusive) that tracks 962 females and 1033 males of all ages from 331 households in 13 Tsimane' villages (Leonard and Godoy, 2008)[ii]. We spent 1995-2001 doing background studies among the Tsimane' to identify villages for the panel study, to gain the trust of study participants, and to refine methods of data collection.

We selected the 13 villages to capture geographic variation in proximity to the market town of San Borja (mean=25.96 km; SD=16.70), the only town along the Maniqui River. The 13 villages of the panel study have slightly taller adults than the other Tsimane' villages. In 2000, we conducted research in 59 Tsimane' villages and took anthropometric measures of adults; the 13 villages of the current panel study were part of the 59 villages surveyed in 2000. Using data from the 2000 survey, we computed height-for-age Z scores using the Frisancho (1990) norms for adults in the 13 villages of the panel study (n=101) and for adults in the other 46 villages (n=405). Adults in the 13 villages of the panel study had, on average, a height-for-age Z score of –1.76 (SD=0.68), compared with the adults in the other villages, who had a height-for-age Z score of –1.98

(SD=0.72). A two-tailed t test for the equality of the two means produced a t statistic of 2.74 (p=0.006).

The panel study in progress currently includes a total of 1995 people, but the sample used in this article includes only people over 22 years of age. The sample used contains a total of 493 people, with 248 females and 255 males. Of the 493 people, 64.49% were present during all five surveys. Seven percent were present during only one survey, 11.97% were present during only two surveys, 6.69% were present during only three surveys, and 10.55% were present during only four survey waves. In the regressions we include a variable for the number of surveys in which we measured the person since temporary or permanent informative attrition might bias results (Gravlee et al., 2009).

We collected annual data during a visit to the village lasting 5-7 consecutive days. We reserved most of those days for interviews, but we also set aside at least one day to take anthropometric measures from all villagers in the village school. Interviews lasted about one hour/adult and usually took place in the home of the participant. Four Bolivian university graduates conducted the survey, and four Tsimane' who worked in the panel study from its inception served as translators.

Outcome variables. The indicators of well-being fall under five broad categories:

Economic:

i) Wealth – we measured the inflation-adjusted (or *real*) monetary value of a person's wealth in 22 modern and traditional physical assets. We added the nominal monetary value of five traditional physical assets (e.g., canoes, bows), 13 modern physical assets (e.g., radios, cutlasses), and four domesticated animals (e.g., chickens, ducks) owned by the adult. Based on ethnographic knowledge of the Tsimane', we selected a range of physical assets to capture wealth differences in the entire sample and between women and men. For instance, the poorest people own bows, arrows, and small animals (e.g., chickens), but better-off people are more likely to own large domesticated animals (e.g., cattle) and expensive industrial goods (e.g., guns). Among the assets we measured, we included assets that women generally own (e.g., bags, pots, small animals), and assets that men generally own (e.g., cattle, guns). We multiplied the quantity of the asset by the selling price of the asset in the village to estimate the value of that asset, and added the value of the different assets to arrive at a monetary measure of total wealth for the person. Current nominal values for wealth were transformed into real values using the consumer price index for agricultural and natural resources of Bolivia[iii].

(ii) Income –we measured the monetary income earned during the 14 days before the day of the interview from the following sources: *(1)* the sale of forest goods, crops, domesticated animals, animal products (e.g., eggs), and *(2)* wage labor in logging camps, cattle ranches, and homestead of highland colonist farmers.

(iii) Deforest – we measured the area deforested for agriculture by the entire household. Study participants reported areas in *tareas*, the local unit of area (1 ha=10 *tareas*). Area deforested provides a reasonable proxy for food consumption and monetary income since Tsimane' clear the forest mainly to grow crops for themselves and to plant rice as a cash crop (Godoy et al., 2009a).

Health: We estimated self-reported morbidity by asking people to report all the days they had been bed-ridden from illness during the 14 days before the day of the interview.

Social: We asked people about their self-reported ability to obtain 100 *bolivianos* in an emergency (1 US$≈8 *bolivianos* during the study period) and coded the variable as one if the person reported being able to borrow this amount, and zero otherwise. We use the variable as a proxy for social capital available to the person when a shock strikes.

Psychological: During the interview surveyors noted whether the person smiled or remained somber. In the analysis the *somber* variable takes the value of one if the person neither smiled nor laughed, or only smiled during the interview, and it took the value of zero if the person laughed during the interview. Elsewhere (Godoy et al., 2005a, 2009c) we review the cross-cultural literature showing the validity of smiles as a reliable marker of mirth.

Human capital:

(i) Schooling was measured by asking people abut the maximum years of completed schooling.

(ii) Math scores were computed from a test in which people were asked to solve four problems; each question was designed to test the participant's ability to add, subtract, multiply, and divide. The answer to each of the four questions was coded as one (correct) or zero (incorrect). We added their score in each question to obtain a total math score (range: 0-4).

(iii) Plant knowledge was measured by asking subjects about their self-reported ability to make traditional objects from local wild and semi-domesticated plants. We first asked a sub-sample of participants (n=50) to list objects made from plants. From that list, we randomly selected 18 objects from 15 different plant species. We then asked people whether they had ever made the objects on their own. We weighted scores to reflect the

fact that only a few people reported knowing how to make difficult objects. The score for an object was inversely proportional to the number of participants who reported knowing how to make the object (Reyes-García et al., 2007).

Explanatory variable: Height Z score. We used the protocol of Lohman et al. (1988) to measure height. We recorded standing physical stature (cm) to the nearest millimeter using a portable stadiometer.

We found evidence of rounding error or digit heaping in height measures. Rounding error is a type of random measurement error since some measures will be rounded up and other measures will be rounded down. If measured accurately, the last digits of measured height should have been evenly distributed among the ten digits. That is, about 10% of the last digits should have been zeros, another 10% should have been ones, and so on. Instead, measures of height ending in the digit zero for all people over 22 years of age over the five surveys accounted for 16.28% of observations among females and for 19.22% of observations among males. We did not correct for digit heaping to retain fidelity to the raw data, but later we discuss the consequences of random measurement error for the causal inferences we make.

We asked people to report their age in years or to show us their birth certificate. Many people indicated they were not sure of their age. A team of Tsimane' and Bolivian researchers spent 2008 verifying and correcting self-reported ages by comparing the self-reported age with the date of major historical events or by comparing the estimates with the ages of adults with known birth dates. We use the estimation made by the TAPS team in the analysis.

Using age, sex, and height data, we computed age and sex-standardized height Z scores based on the norms of Frisancho (1990). From the Z score we created a dummy variable for stunting, which took the value of one if the person was below –2 SD, and zero otherwise. Later, we do sensitivity analysis to make sure that our main results do not hinge on the definition of stunting.

Control variables. These included the person's age, sex, survey year, number of people in the household, a variable capturing the number of surveys in which the person participated, a full set of community dummy variables (n=13-1=12), and body-mass index (BMI=weight in kg/standing height in m^2). We include BMI because of the association between adult stunting and BMI (Dasgupta, 1993; Frisancho, 2003, 2007; Popkin et al., 1996). Since height contributes to BMI, the parameter estimates of stunting may be affected by the collinearity with BMI. For this reason, we later re-estimate the basic regressions without BMI.

Analysis. We use panel linear regressions with individual random effects, clustering by person, and robust standard errors. For the statistical analysis we used Stata for Windows, version 10 (Stata Corporation, College Station, Texas).

The Tsimane': Setting and preliminary findings from research in progress

Setting. The Tsimane' are a native Amazonian society of farmers and foragers in the department of Beni, Bolivia. They number about 8,000 people and have been in sporadic exposure to Westerners since about the early 1950s (Huanca, 2008). Like many native Amazonian societies, they practice hunting, plant collection, and slash-and-burn agriculture, with agriculture and cash cropping of rice becoming the dominant economic activities of households (Vadez et al., 2004). Tsimane' live in small villages of about 20 households (~6 people/household) and, like other native Amazonian societies, practice preferential cross-cousin marriage. The last five decades have seen the spread of modern health care facilities and a secular decline of mortality (Gurven et al., 2007), but no secular change in adult physical stature (Godoy et al., 2006a).

The mean standing physical stature of women and men over 22 years of age were 149.82 cm (SD=8.36) for women and 161.17 cm (SD=12.09) for men. Both Tsimane' women and men were –1.8 SD below the median of their same sex and age peers in the USA using the norms of Frisancho (1990). Of the 493 adult participants, 40.97% were stunted (females=51.53%; males=40.41%; p> χ^2=0.80).

During 2002-2006, Tsimane' experienced an annual growth in BMI of 0.71%/year after controlling for many covariates. During the last year of the panel data used in this article (2006), men and non-pregnant women in the sample had an average BMI of 23.56 and 23.69. Given these BMI values, higher levels of BMI indicated better short-run nutritional status. The annual growth rate in BMI of 0.71% implies that, if continued and if all else remains constant, in a decade, on average, Tsimane' men will have a BMI of 25.29 and Tsimane' women will have a BMI of 25.43, near the upper limit of the range of recent recommendations of a healthy BMI (Brabec et al., 2007). On the negative side, the years 2002-2006 show an increase in the self-reported number of ailments during the two weeks before the day of the interview (+7.35/year)(Godoy et al., 2009b).

Preliminary findings from research in progress. The most important findings from our published research in progress among the Tsimane' that bear directly on this article include: ***(a)*** high rate of childhood growth stunting, with 44.9% of children ages 2-10 years growth stunted (Foster et al., 2005; McDade et al., 2007), owing in part to the pervasiveness of parasitic infections and immune activation (McDade et al., 2005; Tanner, 2005) and due also to a diet adequate in calories but lacking in key micronutrients (Godoy et al., 2005b), ***(b)*** no strong evidence of disparities in anthropometric indicators of short- or long-run nutritional status, perceived health, or modern human capital between girls and boys 2-13 years of age (Godoy et al., 2006b), ***(c)*** high levels of local knowledge of plants (Reyes-García et al., 2003, 2005), ***(d)*** positive associations between local knowledge of plants and child and adult health and conservation of natural resources (McDade et al., 2007; Reyes-García et al., 2007, 2008), ***(e)*** high levels of economic self-sufficiency (Godoy et al., 2007) yet some variation in market exposure, ***(f)*** weather perturbations during gestation and early childhood left an imprint on the height of children and adults (Godoy et al., 2008b, 2008c), and ***(g)*** Tsimane' have low levels of formal schooling, typically about 1-2 years of completed school.

Main results

Table 1 contains the regression results. The most striking result of Table 1 is the absence of any strong association between adult stunting and any of the nine indicators of adult well-being. In fact, adult stunting bore the unexpected sign in most of the regressions. Adult stunting was associated with *higher* levels of wealth, (column [1]; coefficient=0.01, p=0.532), monetary income (column [2]; coefficient=0.06, p=0.196), deforestation (column [3]; coefficient=0.01, p=0.721), school achievement (column [7];

coefficient=0.19, p=0.369), math scores (column [8]; coefficient=0.20, p=0.108), and with a *lower* propensity to be somber during the interview (column [6]; coefficient=-0.01, p=0.576). Only with the perceived ability to obtain credit in an emergency (column [5]; coefficient=-0.006, p=0.732) and with the test of practical ethnobotanical knowledge (column [9]; coefficient=-0.01, p=0.932) did stunting produce results in the direction one might have expected. However, in none of the nine regressions were results statistically significant at the conventional 95% confidence interval or higher.

INSERT TABLE 1 ABOUT HERE

Robustness analysis of main results

Recall from the introduction that the height premium in industrial societies and in traditional rural societies might vary by sex (Nettle, 2002; Pollet and Nettle, 2008; Sear, 2006). To explore the topic, we generated an interaction variable, stunted*male, and included it as an additional regressor in each equation. In none of the new regressions was the interaction term statistically significant at the 95% confidence interval or higher. To control for individual fixed heterogeneity (e.g., child and maternal endowments) we re-estimated regressions [1]-[2] and [4]-[6] using an individual fixed-effect panel linear model and obtained much small coefficients and even weaker statistical results[iv]. We also included a quadratic term for age but found no significant association between stunting and outcome variables. We re-estimated the regressions without BMI to remove possible collinearity with stunting, and found essentially the same results as those shown in Table 1.

In the introduction we noted that the height premium or the stunting penalty may only emerge in more stratified societies and modern, formal economies. To explore the idea we re-estimated the regressions of Table 1 with an additional interaction term, near*stunting. The variable 'near' took the value of one if the village was in the lowest 25% of the village-to-town distance measures and zero if the village was in the top 25% (i.e., farther away). Four of the nine variables were significant, but three of the four variables that were significant had a sign that ran counter to the hypothesized relation. Stunted adults who lived closer to towns had 9.55% (p=0.009) more wealth and 26.67% (p=0.013) more income, and were 13.95% (p=0.002) more likely to have access to credit in an emergency compared with their peers in more isolated communities. However, stunted adults living nearer to towns reported having spent 17.10% (p=0.028) more days in bed due to illness than their peers farther away from town.

Additional analysis

The analysis presented so far is subject to at least two criticisms. First, we may have selected inappropriate outcomes. Stunting might bear no association with socioeconomic indicators of well-being, but it might bear an association with visible indicators of biological well-being, such as reproductive success or musculature. Unfortunately we have no data on reproductive success, but we have data on arm muscle area. Spurr (1983) noted that stunted adults might have reduced muscle mass. To explore the idea we used the age and sex-standardized Z score of arm muscle area using the norms of Frisancho (1990) as an outcome and all the covariates of Table 1. Using an individual random-effect panel linear regression, we found that stunting was associated with 0.17 *lower* standard deviations (p=0.0001) in arm muscle area, with a much stronger negative association among men (-0.22 SD, p=0.0001) than among women (-0.13 SD, p=0.01). This suggests that a further somatic cost of adult stunting could result in reduced adult muscularity, with men incurring the strongest reductions.

The second, more substantive criticism, relates to the definition of stunting. Defining stunting as being below two standard deviations in height relative to one's age and sex peers in the USA is arbitrary and varies upon the standard reference used (Brunson et al., 2008). Defining stunting as <-2SD in Z score for height may reduce our ability to capture variation in a sample population in which nearly half of the individuals meet the criteria for stunted. Under this scenario, those individuals right above and below our cut-off point for stunted may in fact be very similar in actual height. Instead, it might be more illuminating to re-estimate the regressions of Table 1 with ***(a)*** the raw measure of height as a covariate, ***(b)*** a dummy variable for severely stunted, or people below –3SD in height, or ***(c)*** with a locally-based norm of stunting.

We first discuss point ***(a)*** from the previous paragraph. For brevity, we show only the new coefficients for the height variable (measured in cm) for each of the nine outcomes of Table 1. The new regressions were identical to the regressions of Table 1, except that we dropped the variable for stunting and we put instead the raw measure of height. The new coefficients for height were as follow: [1] wealth = -0.002 (p=0.181), [2] income = -0.002 (p=0.541), [3] deforest = 0.0003 (p=0.956), [4] illness = 0.004 (p=0.235), [5] credit = 0.003 (p=0.075), [6] somber = -0.001 (p=0.604), [7] schooling = 0.013 (p=0.391), [8] math = 0.0009 (p=0.920), and [9] ethnobotanical skills = 0.003 (p=0.844). As before, none of the results were statistically significant at the 95% confidence interval or higher.

To address point ***(b)***, we re-estimated the regressions of Table 1 without the dummy variable for stunted; instead we included the dummy variable for severely stunted. We found no significant association in any of the regressions. To address point ***(c)***, we normalized the height variable for each sex and defined stunting as being below 2 SD using the local norm. Again, we found no significant result at the 95% confidence interval.

Discussion and conclusions

Why might adult stunting bear no association with indicators of adult well-being, and what are the implications of the finding for the "small-but-healthy hypothesis"?

One reason for the weak results might have to do with standard methodological shortcomings in any observational study, including random measurement errors in age and height (discussed earlier) and with random measurement errors in some of the outcome variables such as monetary income and credit, which we have discussed elsewhere (Godoy et al., 2008a). The first type of error would generate an attenuation bias and the second type of error would inflate standard errors. Together, they would enhance the likelihood of accepting the null hypothesis of no effect. Though theoretically possible, we doubt this is a major reason for the weak results because other variables for which we have much more accurate measures (e.g., deforestation) (Vadez et al., 2003) or for which we have objective measures (e.g., math skills) also produced weak and counter-intuitive results. Another methodological reason for the weak results might have to do with biases from omitted variables. As noted, stunting is typically ascribed to attributes of the child and of the mother, and to the socioeconomic and demographic environment.

Our use of individual fixed effects controls for the role of individual attributes that remained fixed during the study period, but it does not allow us to control for attributes of the person that changed during 2002-2006.

A second, more substantive, reason for the weak associations between adult stunting and adult indicators of well-being has to do with the presumably adverse consequences of stunting in foraging-farming societies in the early stages of integration to the market economy. In industrial societies, height (a proxy for long-term nutritional status and health) bears a positive association with canonical indicators of adult well-being in part because it is associated with greater cognitive skills and with greater human-capital accumulation, particularly schooling (Case and Paxson, 2006). In a traditional rural society without much schooling or with modest pay-offs to academic skills (Foster and Rosenzweig, 1996), the main mechanisms by which height enhances well-being in industrial societies might be absent, and so height might have no vehicle through which to influence well-being. The other main form of human capital in these societies – local knowledge of the environment, of plants, wild animals, soils, climate, and the like – is learned from trial and error, direct observation, and from one's peers and elders (Reyes-Garcia et al., 2009), and is widely shared (Reyes-García et al., 2003). In industrial societies individuals accumulate human capital credential and academic skills for themselves; these stocks of knowledge for the most part are not shared. Moreover, in a market economy, one's health (or height) might matter much in the formal labor market. But in a traditional rural, highly endogamous, highly autarkic society where all people are linked by kinship bonds of blood and marriage, it is possible that one's individual health might not matter much in the accumulation of human capital since this type of human capital is shared.

What are the implications of our findings for the “small-but-healthy” hypothesis? Other than anthropometric indicators, we have no objective data on health, so our study does not allow us to say much about the association between stunting and health. For the one anthropometric outcome we did use as an outcome, musculature, we found the expected negative association between shortness and this one dimension of objective health. So this part of our analysis would lead us to reject the “small-but-healthy” hypothesis, at least for this indicator of objective health. Though adult stunting might be associated with worse adult objective indicators of health, it does not seem to be associated with worse socioeconomic indicators of well-being, as might have been the case in an industrial setting.

Further investigation should explore the longitudinal dimension of growth patterns to evaluate whether the height premium increases as individuals and communities engage more intensively in market activities. As Tsimane’ engage in these market activities and experience changes in the social fabric that bind the network of shared human capital, height, particularly for men, may emerge as a symbol of status and of economic prestige in this population.

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TABLE 1. Association between indicators of adult well-being (outcome variables) against adult stunting among Tsimane' over 22 years of age: Results of individual random-effect multiple linear regressions with robust standard errors and clustering by individual, 2002-2006 (stunted=<-2SD in height-for-age Z score)

Explanatory variables:	Indicator of well-being (outcome variable):								
	Economic			Health	Social	Psychological	Human capital		
	Wealth	Income	Deforest	Illness	Credit	Somber	School	Math	Plants
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Stunted	0.01	0.06	0.01	-0.02	-0.01	-0.006	0.19	0.20	-0.016
Male	0.42**	0.82**	NA	-0.11**	-0.05*	0.13**	1.49**	1.18**	0.60**
Age	0.006**	-0.003*	0.008**	0.003**	-0.0003	-0.0006	-0.05**	-0.03**	0.04**
BMI	0.01**	0.009	0.01	-0.01	-0.009*	0.005	0.10	0.03*	0.02
House size	0.005	0.002	0.07**	0.01*	-0.002	0.003	-0.08**	-0.07**	0.01
N	2188	2199	979	2210	2171	2193	457	449	299
R squared overall	0.38	0.23	0.18	0.05	0.05	0.05	0.21	0.34	0.33

TABLE 1. Association between indicators of adult well-being (outcome variables) against adult stunting among Tsimane' over 22 years of age: Results of individual random-effect multiple linear regressions with robust standard errors and clustering by individual, 2002-2006 (stunted=<-2SD in height-for-age Z score) - continued

Notes: Cells contain coefficients. ** & * significant at the ≤1% & ≤5% level. Regressions contain robust standard errors, constant, number of surveys in which person participated, and full set of village dummy variables (n=13-1=12), none shown. Log=natural logarithm. NA = not applicable. Dependent variables:
[1] Wealth = natural log of real monetary value of 22 physical assets owned by the person: *(a)* 5 traditional physical assets central to their subsistence (e.g., canoes, bows), *(b)* 13 modern physical assets that capture some luxury goods (e.g., radios) and modern technologies for agricultural production (e.g., cutlasses), and *(c)* 4 domesticated animals (e.g., chickens, ducks). +1 added.
[2] Income = natural logarithm of monetary income earned from sale of goods and from wage labor. +1 added.
[3] Deforest = natural logarithm of area of forest cleared by household. + 1 added. Only for male heads of household.
[4] Illness = natural logarithm of total number of bed-ridden days due to illness during the 14 days before the day of the interview.
[5] Credit = dichotomous variable. 1 = person reported having access to 100 *bolivianos* in an emergency, and zero otherwise.
[6] Somber = dichotomous variable. 1 = person was somber in interview; 0 = person smiled or laughed many times in interview.
[7] School = maximum school grade completed. Ordinary least squares regression only for latest year, 2006.
[8] Math = score in math test to add, subtract, multiply, and divide (range: 0-4). Ordinary least squares regression only for 2006.
[9] Plants = Score in test of practical ethnobotanical knowledge.
Explanatory variables: [a] Stunted=1 if person<-2 SD in height Z score, 0 otherwise; [b] male = 1 if person is male, and zero otherwise; [c] age of person in years; [d] BMI=kg/m^2; [e] household size = number of people in household at time of survey

Reference List

Adair, L.S., 1999. Filipino children exhibit catch-up growth from age 2 to 12 years. Journal of Nutrition, 129:1140-1148.

Beaton, G.H., 1989. Small but healthy? Are we asking the right question? Hum. Org., 48:30-39.

Boersma, B. and Wit, J.M., 1997. Catch-up growth. Endocrine Review, 18:646-661.

Bogin, B. and Keep, R., 1999. Eight thousand years of economic and political history in Latin America revealed by anthropometry. Annals of Human Biology, 26:333-351.

Brabec, M., Godoy, R.A., Reyes-García, V., and Leonard, W.R., 2007. BMI, income, and social capital in a pre-industrial society of the Bolivian Amazon: Interaction between relative and community effects. Am. J. Human Biol., 19:459-474.

Brunson, E.K., Neil, D.B., Leonetti, D.L., and Shell-Duncan, B., 2008. Anthropometric indices: A comparison of three reference data sets. Am. J. Human Biol., 20:215-232.

Cameron, N., Preece, M.A., and Cole, T.J., 2005a. Catch-up growth or regression to the mean? Recovery from stunting revisited. Am. J. Human Biol., 17:412-417.

Cameron, N., Wright, M.M., Griffiths, P.L., Norris, S.A., and Pettifor, J.M., 2005b. Stunting at 2 years in relation to body composition at 9 years in African urban children. Obesity Research, 13:131-136.

Case, A. and Paxson, C.H., 2006. Stature and status: Height, ability, and labor market outcomes. National Bureau of Economic Research, #12466.

Dasgupta, P., 1993. An Inquiry into Well-Being and Destitution. Clarendon Press, Oxford.

Eckhardt, C., Suchindran, C., Gordon-Larsen, P., and Adair, L.S., 2005. The association between diet and height in the post-infancy period changes with age and socioeconomic status in Filipino youths. The Journal of Nutrition, 135:2192-2198.

Engle, P.L., Black, M.M., Behrman, J.R., de Mello, M.C., Gertler, P.J., Kapiriri, L., Martorell, R., and Young, M.E., 2007. Strategies to avoid the loss of developmental potential in more than 200 million children in the developing world. The Lancet, 369:229-242.

Fernald, L.C. and Neufeld, L.M., 2007. Overweight with concurrent stunting in very young children from rural Mexico: prevalence and associated factors. European Journal of Clinical Nutrition, 61:623-632.

Fernand, L.C. and Grantham-McGregor, S., 2002. Growth retardation is associated with changes in the stress response system and behavior in school-aged Jamaican children. Journal of Nutrition, 132:3674-3679.

Foster, A.D. and Rosenzweig, M.R., 1996. Technical change and human-capital returns and investments: Evidence from the Green Revolution. Am. Econ. Rev., 86:931-953.

Foster,Z., Byron,E., Reyes-Garcia,V., Huanca,T., Vadez,V., Apaza,L., Perez,E., Tanner,S., Gutierrez,Y., Sandstrom,B., Yakhedts,A., Osborn,C., Godoy,R.A., and Leonard,W.R., 2005. Physical growth and nutritional status of Tsimane' Amerindian children of lowland Bolivia. Am. J. Phys. Anthro., 126:343-351 pp.

Frisancho,R.A., 2003. Reduced rate of fat oxidation: A metabolic pathway to obesity in the developing nations. Am. J. Human Biol., 15:522-532 pp.

Frisancho,R.A., 1990. Anthropometric standards for the assessment of growth and nutritional status. University of Michigan Press, Ann Arbor, Michigan.

Frisancho,R.A., 2007. Relative leg length a biological marker to trace the developmental history of individuals and populations: Growth delay and increased body fat. Am. J. Human Biol., 19:703-710 pp.

Godoy,R.A., Reyes-Garcia,V., Tanner,S., Leonard,W.R., McDade,T.W., and Huanca,T., 2008a. Can we trust an adult's estimate of parental school attainment? Disentangling social desirability bias and random measurement error. Field Methods, 20:26-45 pp.

Godoy,R., Leonard,W.R., Reyes-Garcia,V., Goodman,E., McDade,T.W., Huanca,T., Tanner,S., and Vadez,V., 2006a. Physical stature of adult Tsimane' Amerindians, Bolivian Amazon in the 20th century. Economics and Human Biology, 4:184-205 pp.

Godoy,R., Reyes-Garcia,V., Vadez,V., Leonard,W.R., Tanner,S., Huanca,T., and Wilkie,D., 2009a. The relation between forest clearance and household income among native Amazonians: Results from the Tsimane' Amazonia panel study, Bolivia. Ecol. Econ., In press..

Godoy,R., Tanner,S., Reyes-Garcia,V., Leonard,W.R., McDade,T.W., Vento,M., Broesch,J., Fitzpatrick,I.C., Giovannini,P., Huanca,T., Jha,N., and Bolivian TAPS Study Team, 2008b. The effect of rainfall during gestation and early childhood on adult height in a foraging and horticultural society of the Bolivian Amazon. Am. J. Human Biol., 20:23-34 pp.

Godoy,R.A., Goodman,E., Reyes-Garcia,V., Eisenberg,D.T.A., Leonard,W.R., Huanca,T., McDade,T.W., Tanner,S., and Jha,N., 2008c. Rain, temperature, and child-adolescent height among native Amazonians in Bolivia. Annals of Human Biology, 35:276-293 pp.

Godoy,R.A., Huanca,T., Reyes-Garcia,V., Tanner,S., Leonard,W.R., McDade,T.W., and Vadez,V., 2005a. Do smiles have a face value? Panel evidence from Amazonian Indians. Journal of Economic Psychology, 26:469-490 pp.

Godoy,R.A., Reyes-Garcia,V., Byron,E., Leonard,W.R., and Vadez,V., 2005b. The effect of market economies on the well-being of indigenous people and on their use of renewable natural resources. Ann. Rev. Anthro., 34:122-138 pp.

Godoy,R.A., Reyes-Garcia,V., Gravlee,L., Huanca,T., Leonard,W.R., McDade,T.W., and Tanner,S., 2009b. Moving beyond a snapshot to understand changes in the well-being of native Amazonians: Panel evidence (2002-2006) from Bolivia. Curr. Anthr., In press.

Godoy,R.A., Reyes-Garcia,V., Leonard,W.R., Huanca,T., McDade,T.W., Tanner,S., Seyfried,C., and TAPS,B.R.T., 2007. On the measure of income and the economic unimportance of social capital. Evidence from a native Amazonian society of farmers and foragers. J. Anthr. Res., 63:239-260 pp.

Godoy,R.A., Reyes-Garcia,V., McDade,T.W., Tanner,S., Leonard,W.R., Huanca,T., Vadez,V., and Patel,K., 2006b. Why do mothers favor girls and fathers boys? A hypothesis and a test of intra-household girl-boy investment disparity. Hum. Nat., 17:169-189 pp.

Godoy,R.A., Zeinalova,E., Reyes-Garcia,V., Huanca,T., Kosiewicz,H., Leonard,W.R., and Tanner,S., 2009c. Does civilization cause discontentment among indigenous Amazonians? Test of empirical data from the Tsimane' of Bolivia. Journal of Economic Psychology, In press.

Grantham-McGregor,S.M., Walker,S.P., and Chang,S., 2000. Nutritional deficiencies and later behavioral development. Proceedings of the Nutrition Society, 59:47-54 pp.

Grantham-McGregor,S., 1995. A review of studies of the effect of severe malnutrition on mental development. The Journal of Nutrition, 8:2233-2238 pp.

Grantham-McGregor,S., Cheung,Y.B., Cueto,S., Glewwe,P., Richter,L., and Strupp,B., 2007. Developmental potential in the first 5 years for children in developing countries. Lancet, 369:60-70 pp.

Gravlee,C.C., Kennedy,D.P., Godoy,R.A., and Leonard,W.R., 2009. Methods for collecting panel data: What can cultural anthropology learn from other disciplines? J. Anthr. Res., 69.

Gray,S., Akol,H.A., and Sundal,M., 2008. Mixed-longitudinal growth of breatfeeding children in Moroto District, Uganda (Karamjoa Subregion). A loss of biological resilience? Am. J. Human Biol., 20:499-509 pp.

Gurven,M., Kaplan,H., and Supa,A.Z., 2007. Mortality experience of Tsimane Amerindians of Bolivia. Am. J. Human Biol., 19:376-396 pp.

Huanca,T., 2008. Tsimane' oral tradition, landscape, and identity in tropical forest. Wa-Gui, La Paz.

Kain,J., Uauy,R., Lera,L., Taibo,M., and Albala,C., 2005. Trends in height and BMI of 6-year-old children during the nutrition transition in Chile. Obesity Research, 13:2178-2186 pp.

Kalanda,B.F., van Buuren,S., Verhoeff,F.H., and Brabin,B.J., 2005. Catch-up growth in Malawian babies, a longitudinal study of normal and low birthweight babies born in a malarious endemic area. Early Human Development, 81:841-850 pp.

Khatun,M., Stenlund,H., and Hornell,A., 2004. BRAC initiative towards promoting gender and social equity in health: a longitudinal study of child growth in Matlab, Bangladesh. Public Health Nutrition, 7:1071-1079 pp.

Komlos,J., 1994. Stature, Living Standards, and Economic Development. The University of Chicago Press, Chicago.

Kuzawa,C.W., 2008. The developmental origins of adult health: Intergenerational inertia in adaptation and disease. In: W.Trevathan, J.McKenna, and E.O.Smith (Editors), Evolutionary medicine and health: New perspective. Oxford University Press, New York, pp. 23-58.

Lagrou,K.C., Froidecoeur,M., Thomas,G., and Massa,C., 2008. Concerns, expectations and perception regarding stature, physical appearance and psychosocial functioning before and during high-dose growth hormone treatment of short pre-pubertal children born small for gestational age. Hormone Research, 69:334-342 pp.

Leonard,W.R., DeWalt,K.M., Stansbury,J.P., and McCaston,M.K., 2000. Influence of dietary quality on the growth of highland and coastal Ecuadorian children. Am. J. Human Biol., 35:837 pp.

Leonard,W.R., DeWalt,K.M., Stansbury,J.P., and McCaston,M.K., 1995. Growth differences between children of highland and coastal Ecuador. Am. J. Phys. Anthro., 98:47-57 pp.

Leonard,W.R. and Godoy,R.A., 2008. Tsimane' Amazonian Panel Study (TAPS): The first five years (2002-2006) available to the public. Economics and Human Biology, 6:299-301 pp.

Liu,Y., Albertson-Wikland,K., and Karlberg,J., 2000. Long-term consequences of early linear growth retardation (stunting) in Swedish children. Pediatric Research, 47:475-580 pp.

Lohman,T.G., Roche,A.F., and Martorell,R., 1988. Anthropometric Standardization Reference Manual (Abridged Edition). Human Kinetics Publishers, Windsor, Ontario.

Martorell,R. and Scrimshaw,N.S., 1995. Effects of improved nutrition in early childhood: Institute of Nutrition of Central America and Panama (INCAP) follow-up study. Journal of Nutrition, 125:1027S-1138S pp.

Martorell,R., 1989. Body size, adaptation and function. Hum. Org., 48:15-20 pp.

Martorell,R., Khan,L.K., and Schroeder,D.G., 1994. Reversibility of stunting - epidemiologic findings in children from developing countries. European Journal of Clinical Nutrition, 48:45-57 pp.

McDade,T.W., Leonard,W.R., Reyes-Garcia,V., Vadez,V., Huanca,T., and Godoy,R.A., 2005. Maintenance vs. growth: Modeling the costs of immune activation for children in lowland Bolivia. Am. J. Human Biol., 17:254 pp.

McDade,T.W., Reyes-Garcia,V., Blackinton,P., Tanner,S., Huanca,T., and Leonard,W.R., 2007. Maternal ethnobotanical knowledge is associated with multiple measures of child health in the Bolivian Amazon. Proceedings of the National Academy of Sciences, **104**:6134-6139 pp.

Messer,E., 1986. The 'small but healthy' hypothesis: historical, political, and ecological influences on nutritional standards. Hum. Ecol., 34:68-77 pp.

Nettle,D., 2002. Women's height, reproductive success and the evolution of sexual dimorphism in modern humans. Proceedings of the Royal Society of London Series B-Biological Sciences, 269:1919-1923 pp.

Panter-Brick,C., 1998. Biological anthropology and child health: Context, process, and outcomes. In: C.Panter-Brick (Editor), Biosocial Perspectives on Children. Cambridge University Press, London, pp. 66-101.

Pelto,G.H. and Pelto,J.P., 1989. Small but healthy? An anthropological perspective. Hum. Org., 48:11-15 pp.

Pollet,T.V. and Nettle,D., 2008. Taller women do better in a stressed environment: Height and reproductive success in rural Guatemalan women. Am. J. Human Biol., 20:264-269 pp.

Pollitt,E., Gorman,K., and Engle,P.L., 1995. Nutrition in early life and fulfillment of intellectual potential. Journal of Nutrition, 125:1111S-1118S pp.

Popkin,B.M., Richards,M.K., and Monteiro,C.A., 1996. Stunting is associated with overweight in children of four nations that are undergoing the nutrition transition. Journal of Nutrition, 126:3009-3016 pp.

Reyes-Garcia,V., Broesch,J., Calvet-Mir,L., Fuestes-Pelaez,N., McDade,T.W., Parsa,S., Tanner,S., Huanca,T., Leonard,W.R., and Martinez-Rodgriquez,M.R., 2009. Cultural transmission of ethnobotanical knowledge and skills: An empirical analysis from an Amerindian society. Social Science & Medicine, In press..

Reyes-Garcia,V., Godoy,R.A., Vadez,V., Apaza,L., Byron,E., Huanca,T., Leonard,W., and Perez,E., 2003. Indigenous people share botanical knowledge. Estimates from an Amerindian society in Bolivia. Science., 299:1707 pp.

Reyes-Garcia,V., McDade,T.W., Leonard,W.R., Huanca,T., Tanner,S., Vadez,V., and Godoy,R.A., 2008. Non-market returns to traditional human capital: Nutritional status and traditional knowledge in a native Amazonian society. Journal Of Development Studies, 44:217-232 pp.

Reyes-Garcia,V., Vadez,V., Byron,E., Apaza,L., Leonard,W.R., Perez,E., and Wilkie,D., 2005. Market economy and the loss of folk knowledge of plant uses: Estimates from the Tsimane' of the Bolivian Amazon. Curr. Anthro., 46:651-656 pp.

Reyes-Garcia,V., Vadez,V., Tanner,S., Huanca,T., Leonard,W.R., and McDade,T.W., 2007. Ethnobotanical skills and clearance of tropical rain forest for agriculture: A case study in the lowlands of Bolivia. Ambio, 36:406-408 pp.

Roos,G., 2009. Nutrition and health. In: C.R.Ember and M.Ember (Editors), Encyclopedia of medical anthropology. Health and illness in the world's cultures. Kluwer/Plenum, New York, pp. 178-184.

Scheper-Hughes,N., 1992. Death without weeping: The violence of everyday life in Brazil. University of California Press, Berkeley.

Sear,R., 2006. Height and reproductive success: How a Gambian population compares to the West. Hum. Nat., 17:405-418 pp.

Seckler,D., 1982. Small but healthy: A basic hypothesis in the theory, measurement and policy of malnutrition. In: P.V.Sukhatme (Editor), Newer concepts in nutrition and their implications for policy. Maharashtra Association for the Cultivation of Science Research Institute, Pune, India, pp. 127-137.

Simondon,K.B., Simondon,F., Imon,I., Diallo,A., Benefice,E., Traissac,P., and Maire,B., 1998. Preschool stunting, age at menarche and adolescent height: a longitudinal study in rural Senegal. European Journal of Clinical Nutrition, 52:412-418 pp.

Spurr,G.B., 1983. Nutritional status and physical work capacity. Yearbook of Physical Anthropology, 26:1-35 pp.

Steckel,R.H. and Rose,J.C., 2002. The Backbone of History. Health and Nutrition in the Western Hemisphere. Cambridge University Press, New York.

Tanner, Susan. A population in transition: Health, culture change, and intestinial parasitism among the Tsimane' of lowland Bolivia. 2005. PhD dissertation, Department of anthropology, University of Michigan.
Ref Type: Thesis/Dissertation

Vadez,V., Reyes-Garcia,V., Godoy,R.A., Apaza,L., Byron,E., Huanca,T., Leonard,W.R., Wilkie,D., and Perez,E., 2004. Does integration to the market threaten agricultural diversity? Panel and cross-sectional evidence from a horticultural-foraging society in the Bolivian Amazon. Hum. Ecol., 32:635-646 pp.

Vadez,V., Reyes-Garcia,V., Godoy,R.A., Williams,L., Apaza,L., Byron,E., Huanca,T., Leonard,W., Perez,E., and Wilkie,D.S., 2003. Validity of self-reports to measure deforestation: Evidence from the Bolivian lowlands. Field Methods, 15:289-304 pp.

Visser-van Balen,H., Geene,R., Kamp,G.A., and Huisman,J., 2005. Motives for choosing growth-enhancing hormone treatment in adolescents with idiopathic short stature: a questionnaire and structured interview study. BMC Pediatrics, 5:1-11 pp.

Waal,W.J. and Verhulst,F.C., 1996. Self-concept before and after two years of growth hormone treatment in intrauterine growth retarded children. Hormone Research, 46:88-94 pp.

Walker,S., Wachs,T., and Meeks Gardner,J., 2007. Child development: Risk factors for adverse outcomes in developing countries. Lancet, 369:145-157 pp.

Walker,S.P., 2007. Early childhood stunting is associated with poor psychological functioning in late adolescence and effects are reduced by psychosocial stimulation. The Lancet, 369:60-70 pp.

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[i] It is still not clear whether childhood stunting in rural areas of low-income nations is reversible (Boersma and Wit, 1997). Some researchers find that stunting (particularly ≤ age 2) is irreversible (Cameron et al., 2005b; Grantham-McGregor et al., 2007; Gray et al., 2008; Kalanda et al., 2005; Leonard et al., 1995; Martorell et al., 1994), but others find evidence of catch-up growth (Adair, 1999; Cameron et al., 2005a; Khatun et al., 2004; Simondon et al., 1998).

[ii] The complete data and its documentation, along with publications from the Tsimane' Amazonian Panel Study (TAPS) project, are available for public use at the following address: http://people.brandeis.edu/~rgodoy/.

[iii] The deflators come from the Unidad de Análisis de Políticas Sociales y Económicas (UDAPE), a policy analysis bureau of the Bolivian government. The information was

downloaded on March 3, 2008 from the following web address of UDAPE: http://www.udape.gov.bo/ (Table 1.1.5, Deflactores implícitos del PIB por rama de actividad económica). The deflators (base=1990) were: 2002=222.23, 2003=231.50, 2004=257.70, 2005=235.14, and 2006=247.85.

[iv] We did not run a fixed-effect individual regression for deforestation because deforestation was measured at the level of the household, and human-capital variables (columns [7]-[9]) did not vary between years.