LONG-TERM (SECULAR) CHANGE OF ETHNOBOTANICAL KNOWLEDGE OF USEFUL PLANTS
Separating Cohort and Age Effects

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Anthropologists, conservation biologists, and psychologists have generally found a long-term (secular) decline of ethnobotanical knowledge among indigenous people. To estimate such knowledge loss, researchers have typically relied on a single cross-sectional data set to (a) measure knowledge among people of different ages, (b) compare measures between ages, and (c) infer a loss of knowledge if the
old knew more than the young. We improve on the approach by simultaneously controlling for cohort effects and age effects—the first refers to the effect of the birth period and the second refers to the effect of the life cycle (or aging). Failure to simultaneously control for both effects may produce the misleading impression that the old know more than the young, and the conclusion that the difference reflects a secular loss of knowledge when in fact it may reflect different positions in the life cycle. We use data collected during 2005 from a native Amazonian society of foragers-farmers in Bolivia (Tsimane') to estimate secular changes in knowledge. Participants included 269 women and 287 men (age ≥20) born 1920–1985. We equate knowledge with theoretical knowledge of useful plants and use cultural consensus to measure knowledge. Multiple regressions were used with knowledge as an outcome and age, birth decade, schooling, and sex as explanatory variables. We find no significant secular change in knowledge in the main analysis, but results were sensitive to (a) the definition and domain of ethnobotanical knowledge and (b) the sample. In the sensitivity analysis we find evidence of a secular increase in knowledge, consistent with the view that knowledge is dynamic and changes.

The oldest hath borne most; we that are young
Shall never see so much, nor live so long
—Shakespeare, King Lear

Because indigenous knowledge (sensu Ohmagari and Berkes 1997) represents humanity's heritage and diversity (Berlin 1992), and because it might enhance indicators of well-being, such as health (McDade et al. 2007; Reyes-García et al. 2008) and the management of natural resources (Reyes-García, Vadez, Tanner et al. 2007), cultural anthropologists, conservation biologists, and psychologists have estimated long-term (secular) changes of indigenous knowledge and, importantly, have tried to understand why it might wane.

Researchers have identified the following causes for the loss of indigenous knowledge: schooling (Boster 1984; Nabhan and St Antoine 1993), occupation (Godoy, Brokaw et al. 1998; Medin et al. 2002; Reyes-García, Vadez, Huanca et al. 2007), market exposure (Brodt 2001), acculturation (Benz et al. 2000; Hill 2004; Lizarralde 2001; Zent 2001), and changes in ecology (Ross 2002a, 2002b; Ladio and Lozada 2004), technology (Atran 2001; Atran et al. 1999, 2004), and values (Ohmagari and Berkes 1997). Together or interactively, these causes reduce exposure to nature and undermine cultural support for the transmission of indigenous knowledge (Wolff and Medin 2001). To estimate long-term changes in indigenous knowledge, researchers have typically relied on a single cross-sectional data set and followed three steps: (a) measure indigenous knowledge among people of different ages, (b) compare measures of knowledge between people of different ages, and (c) infer a loss of knowledge if the old know more than the young. The approach might provide an accurate reading of reality, but it might also provide a misleading impression of knowledge change if the young and the old differ owing to their position in the life cycle. We call the accumulation of knowledge over the life cycle the age effect.
SECULAR CHANGE OF INDIGENOUS KNOWLEDGE

and we call changes in knowledge between birth cohorts the *cohort effect*. Failure to examine both effects simultaneously can bias the inferences made about the secular change in knowledge.

As an illustrative example, consider Figure 1a, adapted from Borjas (2005:330), with a measure of indigenous knowledge on the \( y \) axis and with age in years on the \( x \) axis. Suppose we had three cohorts of people: one born during the 1920s (old cohort, O), one born during the 1950s (middle-aged cohort, M), and one born during the 1980s (young or recent cohort, R). Assume that an additional

![Diagram](image)

**Figure 1.** Indigenous knowledge in relation to age and birth cohort. See text for description of two methods for modeling knowledge acquisition and loss.
year of age produces the same marginal increase ($\beta$) in indigenous knowledge, and that the same annual increase from aging applies to the three cohorts. Suppose that the oldest cohort starts out from a higher initial base of indigenous knowledge than the other cohorts because the habitat contains more wildlife and possibilities of interacting and learning from nature, and because society has more cultural support for the transmission of indigenous knowledge. The intercept of the first cohort would be at $O$; that is, people in the oldest cohort would have started accumulating indigenous knowledge from a high initial base. For simplicity we can assume that people start accumulating indigenous knowledge at an early age (e.g., 5 years), so the intercept captures the amount of knowledge of a young child age five. If ecological degradation set in or if cultural support for the transmission of knowledge broke down between the birth of the first and the second cohort, then the second cohort would start accumulating indigenous knowledge from a lower base (intercept $M$). If ecological degradation or the breakdown of cultural support continued, then the third, youngest, and most recent cohort would start accumulating indigenous knowledge from an even lower base of knowledge (intercept $R$) than the first two cohorts.

A cross-sectional analysis of the association between indigenous knowledge and age that did not simultaneously take into account age effects and cohort effects would rely only on the right-most points of each cohort (in bold) denoted by $O$, $M$, and $R$, and would produce the bias parameter estimate of $\theta$ for age. In the example, this naive identification strategy would lead one to conclude that age bore a strong positive association with knowledge given by slope $\beta$. Figure 1b tells a different story, but again underscores the flawed inferences from insouciance to the simultaneity of age effects and cohort effects. In Figure 1b we show the accumulation of indigenous knowledge starting at, say, 20 years of age for two cohorts. The first cohort, born in 1920, starts accumulating knowledge from intercept $O$, and the second, younger cohort starts accumulating knowledge at a slightly lower intercept ($R$). Both cohorts acquire knowledge over their adult life at the rate of $\beta$ each year. A cross-sectional study that only took into account age effects and no cohort effects would conclude that the older cohort averaged $K_o$ of knowledge and that the younger cohort averaged only $K_r$ of knowledge. Such a study would find a large secular loss of knowledge between the older and younger cohorts given by the difference $K_o - K_r$. In fact, the secular loss of knowledge between the two cohorts would amount to only the difference between the intercepts $O$ and $R$.

The story of the secular change of indigenous knowledge is thus the story of how knowledge changes in relation to birth periods while controlling for age effects. In the study of indigenous knowledge, changes in the amount of knowledge between cohorts might reflect secular changes in variables such as the abundance of wildlife, schooling, cultural support for the transmission of knowledge, occupational opportunities that draw people away from or toward nature, communication or transport infrastructure, and other causes identified earlier. Changes in the amount of knowledge between people of different
ages tend to reflect changes in the life cycle, such as the knowledge that a woman might obtain only after becoming a mother. Differences in knowledge between people of different ages do not necessarily reflect secular changes in knowledge.

In this article we contribute to studies of the secular change in indigenous knowledge by using a method that enables us to separate (a) changes in knowledge that come from aging (age effect) and (b) changes in knowledge that take place between birth cohorts but that are unrelated to aging (cohort effect). We draw on the standard approach used in economics, sociology, and public health to study secular changes in outcomes that remain largely fixed after people reach adulthood (e.g., height, certain types of knowledge) (Borjas 2005; Pretty et al. 1998; Rodgers 1982; Sorkin et al. 1999). If the outcome changes much after adulthood (e.g., practical skills, blood pressure), then the method presented here using only one cross-section of data is insufficient to separate age effects from cohort effects and must be complemented by repeated surveys (Fienberg and Mason 1979). Since all but one of the studies of secular change of knowledge known to us (Zarger and Stepp 2004) rely on a single cross-sectional data set, the method we are about to present should be useful not only to cultural anthropologists but also to conservation biologists and psychologists interested in secular changes of indigenous knowledge. For reasons (discussed below) having to do with random measurement errors in age, with the many domains of indigenous knowledge, and with the multiple goals and questions of researchers, the main contribution of this article lies in the method of analysis rather than in its substantive findings.

For the analysis we estimate the secular change of indigenous or local theoretical ethnobotanical knowledge of useful plants (hereafter ethnobotanical knowledge) with data collected from a foraging-farming society of native Amazonians in Bolivia (Tsimane'; Figure 2).

ASSUMPTION, DATA, AND METHODS

Assumption
Recall that to separate age effects from cohort effects using only one cross-sectional data set, the outcome must remain relatively fixed during adulthood. Previous research suggest that this is a reasonable assumption for theoretical ethnobotanical knowledge of plants, or people’s ability to name but not necessarily use plants (practical knowledge) (Atran et al. 2004; Reyes-García 2001; Reyes-García et al. 2005; Reyes-García, Vadez, Tanner et al. 2007). Several studies (Zarger 2002; Ohmagari and Berkes 1997; Stross 1973; Hunn 2002) suggest that the acquisition of ethnobotanical knowledge peaks by the late teens. We too assume that theoretical knowledge of useful plants remains stable after around 20 years of age, and below we show that the assumption provides a reasonable reflection of reality among the Tsimane’.

Because indigenous practical knowledge of useful plants erodes from lack of use during adulthood (Reyes-García et al. 2005) and because we have only one cross-sectional survey, we cannot estimate the secular change in indigenous practical knowledge of useful plants.
We collected data during June–September 2005 from all households \((n = 252)\) in 13 villages along the Maniqui River, department of Beni, Bolivia. We stress all because the sample did not suffer from an obvious self-selection bias. The survey was part of a panel study in progress that started in 2002 (http://people.brandeis.edu/~rgodoy/). Villages differed in their proximity to San Borja (mean = 25.96 km; SD = 16.70), the only town along the Maniqui River. We collected data on ethnobotanical knowledge from every person over 16 years of age (or younger if they headed a household), but we limit the main analysis to people at least 20 years of age (women = 268; men = 284) to increase the likelihood of excluding people still learning theoretical knowledge. Four surveyors who had worked in the panel study since its inception collected the data.

**Outcome Variable: Theoretical Ethnobotanical Knowledge of Useful Plants**

We do the main analysis with a measure of ethnobotanical knowledge of useful plants. To measure this knowledge we collected similarity judgments using a multiple-choice test of 15 plants selected at random from a list of 92 plants that we compiled in an earlier study (Reyes-Garcia 2001). Because a complete ethnoflora
of the Tsimane’ does not exist, we used free-listing (Weller 1998) to generate a comprehensive list of useful plants known by the Tsimane’ \( (n = 50) \). Informants for the free-listings came from two villages that differed in their proximity to the market town of San Borja. We asked people the following question: “Can you tell me the names of all the useful plants you know?” Ninety-two plants were mentioned by at least two informants, one from each village. We used the list of 92 Tsimane’ plant names to develop the multiple-choice questionnaire.

To construct the multiple-choice questionnaire on plant uses, we randomly selected 15 plants from the list. By doing the selection at random, easy and difficult plants had the same probability of appearing in the test. We asked Tsimane’ whether they could use the plant for any of the following: house building, firewood, food, medicine, or other purposes. For example, we asked: “Can you tell me if X can be used to built a house?” (yes/no), “as firewood?” (yes/no), “to eat?” (yes/no), “as a medicine?” (yes/no). We coded answers as yes = 1, no = 0. After presenting people with the five choices (including “other use”), we asked the same questions for the next plant on the list. We presented the same choices when asking each person about plant uses. We collected information in the form of a matrix with the names of the plants on the x axis and the possible uses of the plant on the y axis.

To analyze multiple-choice data, we calculated the cultural consensus of the group and the individual cultural competence of each individual (Romney et al. 1986; Reyes-García, Byron et al. 2003; Reyes-García, Godoy et al. 2003). Answers to the multiple-choice questionnaire fit the cultural consensus model.

Knowledge scores were transformed into natural logarithms to make the interpretation of results easier. No subject received a zero in the test of theoretical knowledge, so using logarithms did not reduce the number of observations. We have no way of knowing whether measures of theoretical knowledge of useful plants refer to old stocks of knowledge, new stocks of knowledge, or both.

**Age and Birth Period**

We asked people to estimate their age in years. Because many adults did not know their exact age, they guessed, which introduced random measurement error in the estimate of the age variable (Godoy, Leonard et al. 2006). We use the survey year (2005) and the participant’s self-reported age to create dummy variables for the following seven birth periods: \( a \) six birth decades \( (1920, 1930, 1940, 1950, 1960, 1970) \) and \( b \) one birth half-decade \( (1980–1985) \). The dummy variables for birth period took the value of one if the person was born in the indicated birth period (e.g., 1920–1929) and zero otherwise. Since the survey took place in 2005 and we limit the analysis to people over 20 years of age, the youngest cohort included people born during 1980–1985 (inclusive) but excludes those born after 1986. We use people born before 1940 as a reference group to measure secular changes; that is, the secular changes we describe below when presenting the regression results are relative to people born before 1940.

**Analysis**

We use multiple regressions with the logarithm of a person’s ethnobotanical knowledge of useful plants as an outcome variable and with four types of
explanatory variables: (a) dummy variables for the three birth decades (1950, 1960, 1970) and the half-decade (1980–1985), and the person’s (b) age, (c) maximum school attainment, and (d) sex. We pool females and males because we found no significant interaction effects between sex and birth period. For the statistical analysis we used STATA 10 for Windows.

THE TSIMANE’

The Tsimane’ number ca. 8,000 people and live in more than 100 villages scattered along riverbanks and logging roads, mostly in the department of Beni. Tsimane’ subsistence centers on hunting, plant collection, fishing, and slash-and-burn farming (Vadez et al. 2004). Except for a few Tsimane’ who work as schoolteachers, most make their living from the land. Like other native Amazonian populations, the Tsimane’ are highly endogamous and prefer to marry their cross-cousins (Godoy et al. 2008).

In recent publications we provide ethnographic and historical background on the Tsimane’ (Godoy, Reyes-García, Huanca et al. 2005; Godoy, Reyes-García, Leonard et al. 2006; Godoy, Reyes-García, Vadez et al. 2007), including descriptions of their ethnobotanical knowledge (Nate et al. 2001; Reyes-García et al. 2005; McDade et al. 2007), so we limit the ethnographic description below to processes that likely affect secular changes in ethnobotanical knowledge of useful plants.

The first recorded contact between Tsimane’ and Westerners goes back to the seventeenth century, but continual interaction with Westerners dates back only to the late 1940s and early 1950s. During the first half of the twentieth century, Tsimane’ near the town of San Borja worked occasionally as porters for town merchants. They also worked opening cattle trails, constructing the landing strip in San Borja, and helping in small-scale sugar mills. During short spells they hunted for pelts and extracted quinine bark for merchants.

The late 1940s and the 1950s saw many socioeconomic changes in the territory of the Tsimane’. The changes included the establishment of permanent Catholic and Protestant missions, the expansion of cattle ranches, and the establishment of the first schools by Protestant missionaries. From the outset schooling took place in the Tsimane’ language, with Tsimane’ young men working as teachers (Godoy, Seyfreid et al. 2007). Missionaries banned the use of myths and shamans. Most shamans were men, and since they were not allowed to pass on their knowledge to subsequent generations, the occupation of shaman has disappeared (Huanca 2008). The 1970s saw the building of roads across Tsimane’ territory as part of a government policy to reduce the highland population by encouraging migration to the lowlands.

Other agents of change after the 1950s included traveling merchants and various forms of encroachment, such as loggers, oil firms, cattle ranchers, and colonist farmers (Godoy, Jacobson et al. 1998). These encroachers hire Tsimane’, buy crops and forest goods from them, and supply commercial goods and credit (Godoy, Reyes-García, Byron et al. 2005).

To earn money, Tsimane’ work as unskilled laborers in cattle ranches,
logging camps, and in the plots of colonist farmers, or they sell farm crops and forest palms for thatching. Sale of goods take place when traveling traders arrive in the villages, or when Tsimane' take goods to town to sell.

Despite many decades of intermittent exposure to the market economy and Westerners, Tsimane’ retain a high degree of economic self-sufficiency. In a previous study we found that goods bought in the market accounted for only 2.68% of the total value of household consumption of goods (Godoy, Reyes-García, Vadez et al. 2007). Tsimane’ have retained their language and have received little formal schooling. All Tsimane’ speak Tsimane’, but 51.38% of adult women and 7.78% of adult men speak only Tsimane’. Almost half (48.03%) of adult women and 32.21% of adult men have no schooling.

Some of the trends just described would likely erode ethnobotanical knowledge; for example, Protestant missionaries actively discouraged the use of traditional ceremonies, myths, and shamans. But other trends, such as the persistence of economic self-sufficiency, endogamy, and the persistence of the local language, might arrest the loss of ethnobotanical knowledge.

RESULTS

We present the results in three sections. In the next section we provide descriptive analysis of knowledge and bivariate analysis of that knowledge in relation to birth period. In the second section we present results of multiple regressions in which we control for confounders such as age, schooling, sex, and birth period. In the third section we subject the results of the regression analysis to a wide range of checks to ensure the results hold up.

Descriptive and Bivariate Analyses

Table 1 suggests no significant secular change in ethnobotanical knowledge. For example, among women the mean knowledge score increased by 3.44% between women born before 1950 (mean = 0.57; SD = 0.11) and women born during 1970–1985 (mean = 0.59; SD = 0.12). Among men, the mean knowledge score decreased by 1.78% between men born before 1950 (mean = 0.55; SD = 0.14) and men born in or after 1970 (mean = 0.55; SD = 0.14). Bivariate regressions (not shown) suggest that, among women, knowledge scores rose by an average of 0.03%/decade ($p = 0.58$), and among men, knowledge scores fell by an average of 0.10%/decade ($p = 0.56$).

Multiple Regression Analysis

Table 2 contains the results of the multiple regressions. In column 1 we include only dummy variables for birth period to estimate the association between ethnobotanical knowledge and each birth period. In column 2 we include age (and no dummy variables for birth period) as an explanatory variable. In column 3 we include both age and dummy variables for birth periods.

The results in column 1 suggest no statistically significant secular change in ethnobotanical knowledge. Only one birth decade (1970) shows a significant association. People born during the 1970s scored 7.75% higher ($p = 0.032$) than those
**TABLE 1**

Ethnobotanical theoretical knowledge of useful plants among Tsimane’ women and men ≥20 years of age, by birth period (born 1920–1985), measured in 2005

<table>
<thead>
<tr>
<th>Birth period</th>
<th>A. Women</th>
<th>B. Men</th>
<th>C. Difference: Women − Men</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>1920s</td>
<td>12</td>
<td>0.58</td>
<td>0.12</td>
</tr>
<tr>
<td>1930s</td>
<td>23</td>
<td>0.59</td>
<td>0.09</td>
</tr>
<tr>
<td>1940s</td>
<td>19</td>
<td>0.55</td>
<td>0.11</td>
</tr>
<tr>
<td>1950s</td>
<td>25</td>
<td>0.57</td>
<td>0.13</td>
</tr>
<tr>
<td>1960s</td>
<td>48</td>
<td>0.60</td>
<td>0.14</td>
</tr>
<tr>
<td>1970s</td>
<td>68</td>
<td>0.60</td>
<td>0.12</td>
</tr>
<tr>
<td>1980–1985</td>
<td>73</td>
<td>0.58</td>
<td>0.12</td>
</tr>
<tr>
<td>Total</td>
<td>268</td>
<td>0.59</td>
<td>0.12</td>
</tr>
</tbody>
</table>

SE = standard error. *** and ** significant at ≤1% and ≤5%, respectively, in two-tailed t-test comparing difference in mean values between women and men. Mean figures in column C may be slightly off due to rounding.

**TABLE 2**

Results of multiple regressions: Secular change in ethnobotanical knowledge (outcome variable) among Tsimane’ ≥20 years of age (born 1920–1985), measured in 2005 (n = 516)

<table>
<thead>
<tr>
<th>Dependent variable = Theoretical knowledge (in natural logarithms)</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanatory variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth period (reference: &lt;1940)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1940s</td>
<td>0.034</td>
<td>†</td>
<td>0.085</td>
</tr>
<tr>
<td>1950s</td>
<td>−0.046</td>
<td>†</td>
<td>0.046</td>
</tr>
<tr>
<td>1960s</td>
<td>0.039</td>
<td>†</td>
<td>0.174</td>
</tr>
<tr>
<td>1970s</td>
<td>0.077*</td>
<td>†</td>
<td>0.250</td>
</tr>
<tr>
<td>1980–1985</td>
<td>0.007</td>
<td>†</td>
<td>0.214</td>
</tr>
<tr>
<td>Age (years)</td>
<td>†</td>
<td>−0.0004</td>
<td>0.004</td>
</tr>
<tr>
<td>Male (male = 1; female = 0)</td>
<td>−0.048</td>
<td>−0.049</td>
<td>−0.046</td>
</tr>
<tr>
<td>Maximum school grade attained</td>
<td>−0.010</td>
<td>−0.010</td>
<td>−0.010</td>
</tr>
<tr>
<td>Constant</td>
<td>−0.566**</td>
<td>−0.520**</td>
<td>−0.865**</td>
</tr>
<tr>
<td>R²</td>
<td>0.032</td>
<td>0.017</td>
<td>0.033</td>
</tr>
<tr>
<td>Joint significance: birth periods</td>
<td>0.106</td>
<td>NA</td>
<td>0.138</td>
</tr>
</tbody>
</table>

** and * significant at ≤1% and ≤5%, respectively. Ordinary least squares with robust standard errors used when probability of exceeding χ² value in Breusch-Pagan test <5%. † = variable intentionally left out. Joint significance = F-test of joint statistical significance for all dummy variables for birth periods (p > F). NA = not applicable.
born before the 1940s. These results support the findings of the previous section, which suggested no substantial secular change in ethnobotanical knowledge.

Column 2 suggests that age has a negative association with knowledge of useful plants, but the magnitude of the association is small and the result is statistically insignificant. Each additional year of age is associated with a decline of 0.04% in ethnobotanical knowledge ($p = 0.522$).

Once we control for age and birth periods (column 3), we see a secular increase in knowledge of useful plants, but in no case are individual coefficients for birth period statistically significant at the 95% confidence level. As a group, the variables for birth period show no significant association with ethnobotanical knowledge ($F_{5,507} = 1.68, p = 0.138$). The coefficient for the age variable is small (0.004) and statistically insignificant ($p = 0.273$), implying that each additional year of age after a person reaches 20 only increases ethnobotanical knowledge by 0.40%. The finding lends credence to our assumption that knowledge of useful plants can be regarded as a relatively fixed outcome among adults.

Robustness Analysis

We did sensitivity analyses to assess how well the main results of Table 2, column 3, hold up. Changes made to the regression as part of the sensitivity analysis are described in the last column and in the notes to Table 3.

Three noteworthy findings stand out. First, some of the additional analyses confirm the findings presented earlier of no significant secular change in ethnobotanical knowledge (Table 3, rows 5–7). Second, changes in the domain of ethnobotanical knowledge (Table 3, rows 9–11), sample (Table 3, rows 2, 8), and methods for estimating knowledge (Table 3, rows 3–4) produced evidence of significant secular change. Third, when our estimates indicate a secular change, the changes all point to an increase in knowledge of useful plants. All the signs of the statistically significant coefficients in Table 3 were positive and large, suggesting that people born after 1940 have more ethnobotanical knowledge than those born before 1940. For example, people born during the 1950s, 1960s, 1970s, and 1980–1985 scored 25.3%, 46.5%, 54.2%, and 55.4% higher, respectively, than people born before 1940 (Table 3, row 11). Since the age variable contains random measurement error, the secular increase in knowledge is probably larger than our estimates suggest.

DISCUSSION AND CONCLUSION

Methods

Besides stressing the importance of controlling for cohort and age effects, this article highlights four other methodological concerns to keep in mind when making inferences about secular changes of ethnobotanical knowledge.

The first has to do with obtaining accurate estimates of age. In preliterate societies, researchers have found it difficult to obtain accurate estimates of age. With random measurement error in the age variable, one is more likely to conclude, erroneously, that there is no secular change in ethnobotanical knowledge. Gurven et al. (2007) present methods to increase the reliability of age estimates.
<table>
<thead>
<tr>
<th>Row No.</th>
<th>Coefficients of birth period</th>
<th>Joint significance</th>
<th>Description of changes to regression in column 3, Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1940s</td>
<td>1950s</td>
<td>1960s</td>
</tr>
<tr>
<td>1</td>
<td>0.085</td>
<td>0.046</td>
<td>0.174</td>
</tr>
<tr>
<td>2</td>
<td>0.128</td>
<td>0.245*</td>
<td>0.467**</td>
</tr>
<tr>
<td>3</td>
<td>0.195*</td>
<td>0.270*</td>
<td>0.679**</td>
</tr>
<tr>
<td>4</td>
<td>0.106</td>
<td>0.199*</td>
<td>0.397**</td>
</tr>
<tr>
<td>5</td>
<td>0.059</td>
<td>0.264</td>
<td>0.301</td>
</tr>
<tr>
<td>6</td>
<td>0.033</td>
<td>0.024</td>
<td>0.055</td>
</tr>
<tr>
<td>7</td>
<td>-0.044</td>
<td>-0.020</td>
<td>0.021</td>
</tr>
<tr>
<td>8</td>
<td>0.034</td>
<td>-0.039</td>
<td>0.054</td>
</tr>
<tr>
<td>9</td>
<td>0.092</td>
<td>0.165</td>
<td>0.372**</td>
</tr>
<tr>
<td>10</td>
<td>0.123</td>
<td>0.235*</td>
<td>0.408**</td>
</tr>
<tr>
<td>11</td>
<td>0.130</td>
<td>0.253*</td>
<td>0.465**</td>
</tr>
</tbody>
</table>

Same notes as Table 2. Tobit in row 5 is lower-censored Tobit regression. Explanations below match row numbers in Table 3. Row 3: The matching method is sensitive to response bias when measuring similarity. The covariance method is insensitive to response bias but is sensitive to the share of 1’s and 0’s (Batchelder and Romney 1988; Weller and Mann 1997). Bias can inflate the knowledge scores using either method. Row 5: We measured knowledge of how to make salt, fire, and ceramics using traditional methods because ethnographic evidence suggests that they might be dying arts. The simulation allows us to be more confident that our measure of knowledge reflects old knowledge. All three dimensions of skills in row 5 have been replaced by the purchase of industrial substitutes, such as matches, cigarette lighters, metal pots, and iodized salt. Row 9: Refers to an earlier study (2000) of ethnobotanical knowledge. We used cultural competence with 511 households in 58 villages (Reyes-García, Byron, Godoy et al. 2003).
The second topic has to do with robustness checks. Had we limited the analysis to only one way of measuring knowledge, as in Table 2, we would have concluded that there was no secular change in ethnobotanical knowledge and we might have attributed the finding to age measurement error. Changes in sample, definition and domains of ethnobotanical knowledge, and in the methods of computing ethnobotanical knowledge call into question that conclusion and highlight the fragility of results that rely on only one approach.

The third concern has to do with biases from selective migration and mortality. The biases can wreak havoc on the inferences one makes about secular changes of ethnobotanical knowledge. We have not dealt with such biases because we lack data on migration and mortality, but the biases could work in two ways. If a population experienced a secular decline in ethnobotanical knowledge but older adults with less ethnobotanical knowledge were more likely to die at any given age, then estimates of secular changes in ethnobotanical knowledge will produce the flawed impression of a greater loss than actually took place. However, if older people with more ethnobotanical knowledge were more likely to die at any given age, then one would be more likely to erroneously accept the finding of no secular change in ethnobotanical knowledge.

Last, because we generally rely on living people to develop measures of ethnobotanical knowledge and to estimate secular changes in ethnobotanical knowledge, we are constrained by the current stocks of ethnobotanical knowledge; one cannot detect secular changes in ethnobotanical knowledge if the loss of such knowledge was complete and took place in the past because, by definition, no living person would have that knowledge. Our inability to measure old stocks of ethnobotanical knowledge that have disappeared hinders our ability to estimate secular changes in ethnobotanical knowledge accurately.

Substantive Issues
Depending on the particular statistical results, one could conclude that Tsimane’ have experienced no significant secular change in knowledge of useful plants (Table 3, rows 1, 5–7), or a secular increase in such knowledge (Table 3, rows 2–4, 8–11).

The first conclusion dovetails with the findings of other researchers who have found negligible secular change in ethnobotanical knowledge among contemporary populations (Case et al. 2005; Ohmagari and Berkes 1997; Zarger and Stepp 2004). It also dovetails with a study by historical linguists Wolff and Medin (2001). They counted references to trees in the Oxford English Dictionary from 1525 until the twentieth century and found no change in the frequency of words (and presumably in knowledge of trees) until the advent of the Industrial Revolution during the first quarter of the nineteenth century. Only after the advent of major structural transformations in society and in the economy did England witness a secular decline in tree knowledge.

The second conclusion is harder to explain because all the studies known to us have stressed the loss of indigenous knowledge in response to increasing market exposure, whereas we find the opposite. The result could reflect biases from omitting variables, such as selective migration or mortality. But the result could
also reflect the possible positive role of socioeconomic change. Improvements in transport infrastructure have lowered travel costs, making it easier for Tsimane’ to move over a wider area to visit and to work and, in so doing, to learn ethnobotanical knowledge that may not have been readily available to them in the past. In a 2000 study of 58 villages we found that Tsimane’ share plant knowledge widely (Reyes-García, Godoy, Vadez et al. 2003), probably from a strong cultural penchant for movement, travel, visiting, and conviviality (Ellis 1996). If ethnobotanical knowledge is dynamic, then one must be open to the possibility that it may increase, and not that it inevitably wanes.

NOTES

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1. They define indigenous knowledge as “local knowledge held by indigenous peoples, or local knowledge unique to a given culture or society” and add that their definition covers “not only ecological knowledge but other knowledge and skills related to making a livelihood” (p. 199). See also Ellen and Harris 2000.

2. A second, less common approach (Zarger and Stepp 2004) consists of comparing knowledge between people of the same age bracket (cohort) but from cohorts measured at different times.

3. In an earlier study (Reyes-García 2001) we found that each additional year of age among Tsimane’ over 15 years of age was associated with an annual increase of 0.35% in theoretical plant knowledge. Suppose a 15-year-old Tsimane’ knows 100 plants. An annual increase of 0.35% in knowledge suggests that by the age of 65, the 50 extra years of life would have increased knowledge by only 15 more plants. The finding suggests that most of the learning in plant knowledge takes place before people reach adulthood (defined in that study as 15 years of age).

4. Although no household refused to participate, 14 people over the age of 20, representing 2.15% of the total sample of adults, refused to take part in the survey. We might still have a self-selected sample if people with either more or less indigenous knowledge had left the villages before we started the panel study. We do not have data to assess the possibility.

5. See Reyes-García, Martí et al. (2007) for a discussion of definitions of ethnobotanical knowledge. Caniago and Siebert (1998), Zent (2001), and others (Reyes-García, Martí et al. 2007) have equated ethnobotanical knowledge with local indigenous theoretical knowledge of useful plants.

6. When the outcome variable is in logarithms, the coefficient of the explanatory variable in a regression can be read as a percent change in the outcome from a marginal change in the explanatory variable.
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