taps Working Paper Series

# Sib composition and child educational attainment: Theory and evidence from native Amazonians in Bolivia

Wu Zeng, Karla Rubio Jovel, Eduardo A. Undurraga, James Broesch, Dan T.A. Eisenberg, Colleen Nyberg, Susan Tanner, Victoria Reyes-Garcia, Thomas W. McDade, William R. Leonard, Yuan Ma, Tomas Huanca, Ricardo Godoy, TAPS Bolivia Study Team

Tsimane' Amazonian Panel Study Working Paper # 60

Sib composition and child educational attainment:

Theory and evidence from native Amazonians in Bolivia

WU ZENG,[1] KARLA RUBIO JOVEL[1], EDUARDO A. UNDURRAGA[1], JAMES BROESCH[2], DAN T.A. EISENBERG,[3] COLLEEN NYBERG,[4] SUSAN TANNER[5], VICTORIA REYES-GARCÍA,[1, 6] THOMAS W. MCDADE,[3] WILLIAM R. LEONARD,[3] YUAN MA,[1] TOMÁS HUANCA,[7] TAPS BOLIVIA STUDY TEAM,[8] AND RICARDO GODOY,[1, *]

[1]Heller School, Brandeis University, Waltham, MA 02454, USA

[2]Department of Anthropology, Emory University, Atlanta, GA 30322, USA

[3]Department of Anthropology, Northwestern University, Evanston, IL 60208, USA

[4]Department of Anthropology, U Mass, Boston, Boston, MA 02126, USA

[5]Department of Anthropology, University of Georgia, Athens, GA 30602, USA

[6]ICREA and Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, 08193 Bellatera, Barcelona, Spain

[7]CBIDSI-Centro Boliviano de Investigación y Desarrollo Socio Integral, Correo Central, San Borja, Beni, Bolivia

[8]Tsimane' Amazonian Panel Study, Correo Central, San Borja, Beni, Bolivia

*To whom correspondence should be addressed. E-mail: rgodoy@brandeis.edu

**Word count:** 12,864

*ABSTRACT*
Motivation. The neoclassical theory of human capital posits that insufficient household resources and a wage premium for males should induce parents to skew investments to educate boys over girls because males will earn more from schooling. If so, the age and sex composition of siblings should affect child educational attainment because an additional child would dilute the amount of educational investments between children. Research over the last 15 years has produced ambiguous findings about the effects of sib composition on child educational attainment in part because most studies have come from wealthier societies where resource constraints are less binding.
Aim. Drawing on data from a rural society of foragers-farmers of native Amazonians (Tsimane') in a poor nation (Bolivia) we estimate the effect on the educational attainment of children <5-16 y of having an additional younger sister, older sister, young brother, and older brother.
Methods. Data was collected during 2007 from 575 children (girls=277; boys=298) in 232 households of 13 Tsimane' villages. The principal caretaker was asked about the number of living brothers and sisters from the same mother of each child, and the age, school enrollment, and maximum school attainment of the child. Surveyors tested children's skills in math, writing, reading, and proficiency in spoken Spanish. Household fixed-effect regressions were run with measures of educational attainment or skills as outcomes; covariates included the child's sex, age, and number of younger sisters, older sisters, younger brothers, older brothers.
Results. Holding constant sib size, another older brother or sister was associated with a lower probability of the child ever attending school. Among those who received education, another older sibling was associated with completing fewer years of schooling. Having more older siblings indirectly affects the child's skills through maximal education received. But no direct affect of elder siblings on children's academic skills were consistently observed after controlling for children's education attainment.
Conclusions. Additional elder siblings erode resources for younger siblings to accumulate modern human capital, lowering the probability of being ever educated at school and reducing education attainment. By lowering the probability of attending school, elder siblings undermine a child's academic skills. The study underscores the importance of measuring sib composition in studies of human capital returns, a cross-cultural approach in such studies, and the use of different indicators of modern human capital to obtain a comprehensive view of sib composition's effect on well-being.

*Key words*: Bolivia, Tsimane' Amazonian Panel Study (TAPS), human capital, brothers, sisters

From the late nineteenth century onward, researchers have shown interest in how the demographic composition of the household – including number of people and siblings in the household, birth spacing, and birth order –affect outcomes such as achievement, IQ, health, personality, and educational attainment (Hauser and Kuo 1998; Steelman et al. 2002). As part of this broad interest, researchers over the past 15 years have started to examine how the age and the sex composition of siblings (hereafter sib composition) might affect children's educational attainment (Butcher and Case 1994; Dayioğlu et al. 2009; Steelman et al. 2002). We equate *educational attainment* with a child's maximum school grade achieved and with academic and language skills. Later we justify the definition. We use *educational attainment* and *modern human capital* interchangeably.

Much of the empirical work on how sib composition might affect child educational attainment has been guided by the neoclassical theory of human capital (Becker 1960; Becker and Lewis 1973; Becker and Tomes 1976; Buchmann 2000; Behrman 1997). The theory starts by assuming that parents try to maximize the educational attainment of all their children, but if parents do not have enough income, wealth, or time to invest equally between all their children, they will skew investments to the offspring with the potential of earning the highest wage as an adult. If the labor market favors males over females, or if society has a pro-male bias, then parents will invest more educating sons than educating daughters. Under such conditions, holding constant the number of siblings in the household, then having more sisters will raise the educational attainment of boys, but having more brothers will erode it because brothers compete for and dilute the amount of parental resources to invest in the education of offspring.

The neoclassical theory has served well to explain why parents might skew educational investments toward children of one sex over the other in response to signals from the market or from society, but it does not explain why or how older or younger siblings might affect a child's educational attainment. For example, in a society with a pro-male bias and a wage premium for male workers, it may not be any additional brother who competes for resources and lowers the educational attainment of other brothers, but only an additional older (or younger) brother.

A fruitful way to build on the neoclassical theory of human capital is to examine how specific sibling categories might affect educational attainment. Across cultures, most children are embedded in a network of rights and obligations with four sibling categories: older sisters, younger sisters, older brothers, and younger brothers. Cultural norms shape what a child can expect and what a child must offer another sibling of the dyad. If the resource costs of maintaining a dyadic relation with a particular category outweigh the benefits to the child, then having more siblings in that category should lower the school attainment of the child. For instance, if cultural norms dictate that older sisters should take care of younger sisters (but not of younger brothers), then having an additional younger sister (but not an additional younger brother) will lower the school attainment of a girl but will not lower the school attainment of a boy.

As the literature from sociology and psychology suggests, the four sibling categories might affect educational attainment through other paths besides mutual rights and obligations. For instance, older sisters or older brothers might serve as role models

(Widmer and Weiss 2000), or younger brothers and younger sisters might provide an opportunity for older siblings to act as teachers, and thus enhance the cognitive abilities and academic skills of older siblings (Smith, 1990; Zajonc, 2001; Zajonc and Mullally, 1997).

Because of its parsimony and clarity of predictions, the neoclassical theory of human capital has been used widely by economists (e.g., Butcher and Case 1994; Morduch 2000; Dayioğlu et al. 2009) and by sociologists (e.g., Downey 1995, 2001; Kuo and Hauser 1997; Steelman et al. 2002; Guo and VanWey 1999; Van Eijck and de Graaf 1995; Buchamann 2000; Wei and Kuo 2006; Cyrus et al. 2007; Conley 2000; Stealman and Mercy 1980) to estimate how sib composition (mainly sisters vs. brothers) affects child educational attainment. As we shall, empirical results have produced conflicting findings, in part because of the choice of research site. With few exceptions discussed later (Morduch 2000; Buchmann 2000), studies of the effects of sib composition on the educational attainment of children have come from affluent societies, often from cities and typically from the USA. Studies in such settings have the obvious advantage of being able to draw on large samples from publicly available, often nationally representative, datasets. But the neoclassical theory of human capital suggests that the age and the sex composition of siblings should affect educational attainment not so much in affluent societies, but in settings where parents face severe resource constraints, more likely to take place in the countryside of poor nations. Of course, in rural settings of poor nations, nuclear families form part of larger kin groups, which could attenuate a household's resources constraint and change how sib composition affects the educational attainment of children. Further, with a fluid sexual division of labor, as happens in many poor rural societies (Conley 2004), parents might not have to skew resources to children of one sex over the other. Thus, even in a poor rural setting, theory provides insufficient guidance on what to expect. Only empirical analysis and a cross-cultural approach can help solve the ambiguity.

The main aim of this article is to contribute to the literature on sib composition and educational attainment of children with data from a rural society in a poor nation. We leave aside how other aspects of household demographics (e.g., household size, birth order) might affect the educational attainment of children because those topics have received more extensive treatment than sib composition (Black et al. 2005; Conley 2004; Rodgers et al. 2000). Drawing on cross-sectional data collected among children of school age in a foraging and horticultural society of native Amazonians in Bolivia, the Tsimane', in this article we build on the neoclassic theory of human capital to test three hypotheses:

*H1:* The age and sex composition of siblings will have an ambiguous effect on child educational attainment owing to countervailing forces. Economic constraints will be more severe in a foraging-horticultural society than in an affluent industrial society, so sib composition should produce sharper effects. However, through bonds of kinship and reciprocity households in foraging-horticultural societies form part of larger social networks, which should ease the resource constraints of the households.

*H2:* Holding constant the sex of the additional sibling, an additional older sibling will have ambiguous effects on a child's educational attainment because the net effect will depend on forces pulling in opposite directions – investment of resources in the additional sibling counterbalanced by transfers from the additional sibling.

*H3:* If an additional sibling in a sib category (e.g., an additional older sister or an additional younger brother) affects the educational attainment of a child, the effects should be more marked and more readily visible among poorer households than among wealthier households because poorer households face more severe resource constraints than wealthier households.

## The effects of sib composition on the educational attainment of children: The evidence

Here we review empirical studies, summarize the main points, and note gaps in methods, some of which we try to address. We first review studies done in the USA, and then review studies done overseas.

### *a. USA*

In a widely-cited study done among Whites, Butcher and Case (1994) analyzed 3,852 people (females= 2,025 males=1,827) from the Panel Study of Income Dynamics (PSID) of 1985, 1,724 women from the National Longitudinal Survey of Women (NLSW) of 1984, and 22,826 women from the Current Population Survey (CPS) of 1989. They found that the sex composition of siblings did not affect the educational attainment of males, but did affect the educational attainment of females. In the three samples they found that after controlling for family size and family background, women who were raised with only brothers received more education than women who were raised with any sister. For example, in a household with two children, a woman with a brother received 0.50-0.20 more years of schooling than a woman with a sister. In the NLSW and PSID samples another sister reduced a woman's education by 0.30-0.25 years, with smaller effects among younger cohorts. Among females 45-65 years of age, having a sister reduced by 9% and by 13% the probability of finishing high school and college. Among the younger cohort of females (24-44 years of age), having a sister reduced the probability of going to college by 8%.

Subsequent studies have not confirmed in full the findings of Butcher and Case. Hauser and Kuo (1998) used three datasets to examine the effects of sib composition on educational attainment: 1973 Occupational Changes in a Generation Survey (OCG II) (n=19,362), the 1986-1988 Surveys of Income and Program Participation (SIPP) (n=17,505), and the 1989 National Survey of Families and Households (NSFH) (n=3,948). They produced 24 estimates for the effects of sisters on educational attainment, and found that only 10 of the effects had the negative sign expected from the study by Butcher and Case, and none of the 10 effects was significant at 5% confidence level. Unlike Butcher and Case, they did not find consistent trends across birth cohorts. Elsewhere, Kuo and Hauser (1997) study 5,626 groups of siblings from the Wisconsin Longitudinal Study (WLS) and again find no effect of sib composition on educational attainment. As Conley (2000) notes, the absence of significant effects in the studies by Hauser and Kuo may stem from having done the analysis using different sib groups (e.g., only two siblings, only three siblings) and thus losing statistical power to detect effects in the pooled sample.

Like Hauser and Kuo, Kaestner (1997) was unable to replicate the results of Butcher and Case. Kaestner used ~5,000 child-year observations collected during 1958-

1965 by the National Longitudinal Survey of Youth (NLSY). He found no effects of the sex composition of sibling on the educational attainment of White males or White females. However, among Black adults, those who grew up with a sister or who had more sisters had higher educational attainment than those who grew up without sisters or with fewer sisters. Among Blacks, the benefits of having sisters were stronger for males than for females. Among children and teenagers, they found some statistically significant results linking sibling sex composition and scores in the Peabody Individual Achievement Test (PIAT) and in the Armed Forces Qualification Test (AFQT) tests, but results were not consistent between ages, sex, race, or sib composition.

Conley (2000) used a sample of 7,573 people from the 1989 survey of PSID to estimate the effects of having siblings of the opposite sex on a child's educational attainment. The sample included only household heads 25-65 years of age with at least one sibling. For males, each additional brother and each additional sister lowered school attainment by 0.10 and 0.16 years. Among females, another brother or another sister lowered school attainment by 0.10 and 0.06 years. His finding that sisters caused more harm to brothers, and that brothers caused more harm to sisters contradicts Butcher and Case conclusion about the adverse effects of having sisters for the school attainment of females.

***b. Overseas: Industrial and poor nations***

As Steelman et al. (2002) note, the effects of sib composition on child educational attainment will likely vary across cultures. Across cultures, definitions of sib and family vary, and so does the organization of the household economy, all of which might produce different results from those found in the USA.

Wei and Kuo (2006) studied the relation between educational attainment and sib composition in Taiwan using a nationally representative sample of 12,715 people from 3,001 families from the Panel Study of Family Dynamics (PSFD) done during 1999-2003. They found that wider spacing among siblings was associated with less educational attainment for first-born females. Also in Taiwan, Cyrus et al. (2007) studied 10,764 children from 2,626 families using data from PSFD and found that an additional sibling (particularly a younger sibling rather than an older sibling) was associated with 0.21 fewer years of schooling for females, but not for males. They hypothesize that additional (younger) siblings reduced the educational attainment of girls because older sisters are forced to work and leave school earlier to support younger siblings, particularly younger brothers. Parish and Willis (1993) found similar results in Taiwan. Using data from the 1989 Taiwan Women and Family Survey, they found that older sisters had a positive effect on male and female educational attainment. One more older sister was associated with 0.18 ($p<0.05$) and with 0.26 ($p<0.05$) more years of completed schooling among girls born during the decades of the 1960s and the 1970s, and was associated with 0.26 ($p<0.05$) and 0.13 ($p<0.05$) more years of completed schooling for boys at the same time frame. But younger sisters had the opposite effect. During the same two decades, having another younger sister was associated with 0.19 ($p<0.05$) fewer years of completed schooling.

Morduch (2000) studied 2,104 Tanzanian and 1,625 South African children 13-16 years of age. He used the 1993 South Africa Integrated Household Survey and a nationally representative survey of 5,000 households from Tanzania done at the national level in 1993. He found weak associations between sib composition and educational attainment. For example, in Tanzania moving from having four brothers to having four sisters increased the educational attainment of either girls or boys by 0.44 years, but the result was statistically significant only at the 90% confidence interval (t=1.46). Buchmann (2000) surveyed 596 households (urban=196, rural=400) in Kenya and found no significant effect of sib composition on children's school enrollment.

In one of the more recent studies on the effects of sib composition on schooling, Dayioğlu et al. (2009) studied 1,733 people from the 1998 round of the Turkish Demographic and Health Survey (DHS) and estimated how current school enrollment (not educational attainment) varied in relation to *(i)* the number of older or younger sisters and brothers and *(ii)* socioeconomic status. They restricted their analysis to cities because of the difficulties of estimating socioeconomic status or wealth in rural areas. They found significant results, but only among females, and chiefly in the lower socioeconomic gradients. A female who had an additional brother (but not an additional sister) was 16-18% less likely to enroll in school than an otherwise identical female without an additional brother. Among female children in households at the bottom 40% of the income distribution, moving from a household with only sisters to a household with only brothers reduced the probability of school enrollment by 17.8-14.6%. Among households in the top 20% of the income distribution, moving from a household with only sisters to a household with only brothers increased the probability of school enrollment of females by 10.6-13.8%, consistent with the result of Butcher and Case (2004). They do further analysis and find that it is the addition of an older brother that harms most the likelihood of school enrollment of girls. In sum, it is chiefly older brothers from poorer households that have the greatest (negative) effect on the probability of school enrollment for females (but not for males).

Dammert (2010) used data from the 2000 Guatemala Living Standards Measurement Study and the 2001 Nicaragua Living Standards Measurement Study. The sample included 4,694 and 7,276 households at the national level and individual-level information for 22,576 and 37,771 people in Nicaragua and Guatemala. She found no strong general effects of sib composition on school attainment, with one exception. Males with younger sisters had a seven percentage-point greater probability of attending school in Nicaragua and an eight percentage-point greater probability of attending school in Guatemala.

### *c. Summary*

Three overlapping topics merit discussion: ***(i)*** the effect size of sib composition, ***(ii)*** the reasons for the diversity of results, and ***(iii)*** methodological lessons from the empirical studies.

***(i)*** Effect size. Except for the study by Dayioğlu et al. (2009) and Dammert (2010), most of the effect sizes are small or statistically insignificant. For example, in the USA, Conley (2000) found that an additional sibling of the opposite sex lowered the level of school attainment by 0.12 (female + brother) and 0.16 years (male + sister). Butcher and Case (1994) found that an additional sister reduced the educational attainment of a woman by 0.25-0.30 years. Hauser and Kuo (1998; Kuo and Hauser

1997), Kaestner (1997), and Buchmann (2000) did not find consistent evidence to support a relation between sib composition and educational attainment.

***(ii)*** Reasons for diversity of results. The diversity of results could reflect different model specifications, sample selection, and sample size. For instance, Dayioğlu et al. (2009) use twin births as an instrumental variable for the number of siblings (but not for sib composition) and found that estimates using ordinary least squares (OLS) differed from those using two-stage least squares. Human capital theory suggests that the importance of sib composition should vary in relation to the economic constraints of the household, yet some studies do not control for social class (Kuo and Hauser 1998), exclude some of the most marginalized groups (e.g., Blacks) among whom one would expect sharpest results (Butcher and Case 1994), or only include permanent income in the form of household durables and household facilities (Dayioğlu et al. 2009). Non-significant results could also result from having analyzed sub-groups of siblings with small samples (Kuo and Hauser 1998).

***(iii)*** Methodological lessons. Four methodological lessons emerge. First, obtaining unbiased estimates of the effect of sib composition on educational attainment is hard because one must control for sib size, birth order, and birth spacing. Because these variables overlap, accurate estimates of sib's effect must draw on large samples. Second, sib composition is endogenous (Dammert 2010; Guo and Van Wey 1999). Parental preferences about ideal family size, sex of offspring, and birth spacing likely affect both sib composition and school attainment of children. Dayioğlu et al. (2009) use instrumental variables (e.g., twin births) for sib size, but no researcher to the best of our knowledge has identified an instrumental variable for one of more of the sib categories.

Third, parental resources tend to affect formal educational attainment more than cognitive or academic skills (Steelman et al. 2002), making it necessary to measure both educational attainment and academic or cognitive skills to obtain a comprehensive view of how sib composition affects human capital. Last, if one wishes to identify the sibling category that harms or benefits educational attainment, one must include the number of siblings in each of the four sibling categories: older sisters, younger sisters, older brothers, and younger brothers. To our knowledge, only Dayioğlu et al. (2009) have taken this approach.

We try to overcome some (but not all) of the shortcomings. We are unable to draw on a large sample or use instrumental variables for sib composition. We avoid producing a small sample by using interaction variables instead of doing separate analysis for females and males. Since we have multiple observations for households, we use a model with household fixed-effects, which removes the role of fixed attributes of the household (e.g., parental preferences and resources at the time of the study, household size, sib size and community fixed attributes). The use of a household fixed effect model helps to remove some of the endogeneity biases. We have measures of both permanent income (in the form of physical assets) and transitory income (in the form of monetary earnings and farm output), both of which we use to explore how results vary in relation to socioeconomic status. For outcomes, we measure maximum school attainment and various forms of academic and language skills (described later). Last, for each person we measure the number of the four sibling categories: number of younger sisters, older sisters, younger brothers, and older brothers.

**Materials, variables, and analysis**

***(i)*** Materials. Data come from the 2007 survey of an annual panel study among all Tsimane' in 13 Tsimane' villages along the Maniqui River, department of Beni, Bolivia (Leonard and Godoy 2008; project web site: http://www.tsimane.org/). The panel study started in 2002 and continues at the time of this writing (2010). We picked the 13 villages to capture geographic variation in closeness to the market town of San Borja (mean village-to-town distance = 25.96 km; standard deviation [SD] = 16.70), the only town along the Maniqui River. For this article we use only the 2007 survey because it is the first time we asked about all living brothers and sisters of every person in the study and the age of first union among adults or people heading households.

The 2007 survey had 575 children (females=277; males=298) of school age (5-16 years of age). The children came from 232 households, and none headed a household. Data from the panel (2002-2006) suggests that children <16 years of age (girls=181; boys=229) first enrolled in school at the age of 6.18 years (SD = 1.37). A two-tailed test comparing mean difference between girls and boys in the age when they first enrolled in school yielded no significant difference between the sexes (t=1.39, p=0.163). The mean age of enrollment for girls, 6.28 (SD=1.56), was almost the same as the mean age of enrollment for boys, 6.09 (SD=1.20).

We have no data on when children stop attending primary school, but we limit the analysis to children ≤ 16 years of age because shortly thereafter Tsimane' set up their own households and generally stop attending school. The median age of first union for females was 16 (SD=3.14) and the median age of first union for males was 19 (SD=3.14).

Measures of modern human capital among the children in the sample fell below measures of modern human capital among children in the rest of the Tsimane' population. In 2008 we did a health survey in 40 villages outside of the area of the panel study, which allows us to compare measures of modern human capital between children in the two samples. As just noted, children in the panel study first enrolled in school at the age of 6.18 years; children in the other villages (n=1,113) first enrolled in school at the age of 6.12 years. Our sample is therefore representative of the Tsimane' population in age when children start school. But in other measures of modern human capital the two samples differ. Controlling for the age and the sex of the child, children in the sample for this study had 0.71 fewer years of schooling, 20.60% lower score in the math test, 21.25% lower probability of reading Spanish, 30.34% lower probability of being able to write, and 22.77% lower probability of speaking fluent Spanish. All results were statistically significant above the 99% confidence interval. Nevertheless, children in the panel study had more variation in modern human capital. For example, the coefficients of variation (SD/mean) of maximum education and math score were 1.17 and 1.61 among children in the panel study, compared with only 1.00 and 1.32 among children in the rest of the Tsimane' population.

These sample characteristics work in our favor. Lower levels of modern human capital among children likely proxy for more resource constraints; this should sharpen the effects of sib composition on child educational attainment. And greater variability in outcomes should enhance the likelihood of finding significant results.

Four Bolivian university graduates did the surveys and four Tsimane' who worked in the panel study from its beginning translated. To improve rapport with study participants, surveyors and translators interviewed the same people across years so the subjects in the 2007 study knew the surveyor and translator. The survey took place in the home of the study participant. Surveyors directed questions about child attributes to the child's principal caretaker, generally the mother. Measures of writing, reading, language, and math skills came directly from the child through tests or through direct observations, as described next.

***(ii)*** Variables. Appendix 1 contains a summary of how we measured the outcome variables. Here we expand briefly on some of the methods. Recall from the earlier discussion that sib composition might have different effects on formal school attainment (e.g., maximum school grade completed) and academic or cognitive skills. For this reason, we measured both formal school attainment and academic skills. In the discussion that follows, words in italics stand for the name of the variable as they appear in the tables or in the model specifications.

Outcome variables: Schooling. Surveyors asked the child's principal caretaker whether the child had been or was enrolled in school (*enrolled*) (n=504) and the maximum school grade completed by the child who had any education (n=295) (*maximum*). For school-age children who had never been enrolled in school the maximum school grade was set as zero.

Outcome variables: Skills. During the survey, surveyors – all native speakers of Spanish – could judge the child's ability to speak Spanish, Bolivia's national language, by posing simple questions in Spanish to the child. The variable *Spanish* was coded as one if the child was fluent or spoke some Spanish, and zero if the child was monolingual in Tsimane'. Since surveyors and translators had tracked the same people over at least five years, they had reliable information to judge language competence. Measures of skills in *math*, *writing*, and reading (*literacy*) came from short tests given by surveyors to the child at the time of the survey.

Explanatory variables: Sib composition *(Sibcom)*. For all the children in the household, surveyors asked the female head of the household for the number of living younger sisters, older sisters, younger brothers, and older brothers of the child. To reduce measurement error in sib composition we only asked about siblings from the same mother and only coded whether the same-sex siblings were older or younger than the target child about whom we were eliciting information. The measure of sib composition has three limitations. First, it did not include half siblings on the father's side. Second, it did not take into account siblings who died during childhood but who may have influenced the allocation of parental investments in living children. Third, we did not measure birth spacing owing to faulty recall by Tsimane' adults when reporting own or child age. We use *Sibcom* here to represent the general form of sib composition in model specifications that follow. When running the models, *Sibcom* might take different forms (e.g., four sibling categories; *older siblings* vs. younger siblings; *sister* vs. brothers; *siblings with the opposite sex* vs. siblings with the same sex).

We checked the consistency of the sib data. Even though we asked mothers to report the total number of living school-age children they had at the time of the survey, they may have answered with error. This could have happened if they reported children who had died. We assumed that the most frequently reported number of total siblings of all school-age children in a household is the most precise measure of sib size, and excluded observations where the total number of siblings for the child differs from that number. As a result, we dropped 34 observations from the analysis.

Explanatory variables: Parental wealth and parental income. To test the third hypothesis about how the effects of sib composition might vary in relation to resource constraints, we used two variables, one to proxy for parental permanent income and one to proxy for parental temporary income. For permanent income we used wealth. We estimated the wealth of each household head by measuring the monetary value of 22 physical assets owned by each head at the time of the interview. We then added the wealth of the female and the male head of the household and divided the total by the number of male adult equivalents in the household (Appendix 2).

We equate income with the total area of old-growth forest and fallow forest cleared by the household during the year before the interview, divided by the number of male adult equivalents. Area cleared is a reasonable proxy for temporary income among Tsimane' because Tsimane' clear forest to plant annual and perennial crops for sale and for their own consumption. The measure of temporary income understates true temporary income because it excludes monetary earnings from wage labor and from the sale of forest goods (e.g., firewood, timber) and consumption of forest and farm goods. Elsewhere (Vadez et al. 2003) we compared reports by adults of forest area cleared with objective measures of area cleared collected by researchers, and found that Tsimane' report with accuracy the area of forest cleared.

From measures of parental wealth, we created a variable called *poor*, which took the value of one if the household was in the bottom half of the wealth distribution and zero otherwise; we use the variable in Table 3A. From measures of area deforested, we created a variable also called *poor*, which took the value of one if the household was in the bottom half of the distribution of area deforested, and zero otherwise; we use the variable in Table 3B.

Control variables. These included the age of the child (*age*) and the child's sex (*male*=1; female=0), both of which in principal applied to all the models regarding all the six indicators. But the variable *male* was dropped from some models due to perfect collinearity. When we quantified the direct impacts of sib composition on skills we controlled for *maximum* completed education to partial out its indirect impact though schooling.

***(iii)***. Model and analysis. We ran household fixed-effects models to remove possible confounding effects from fixed household characteristics (e.g., resources and sib size), and used clustering by households to adjust for multiple observations in a household; 83.62% of the 232 households with children had at least two children.

To model the effect of sib composition on years of schooling, we used a two-part model (Heckman 1976) because it can accommodate many zeros in outcome variables. Forty-three percent of children (n=233) in our sample had no schooling (*enrolled*=0 or *maximum* =0).

The first step of the two-part model was to use a logit model to estimate the impact of sib composition on the probability of enrolling in school

$$\ln\left(\frac{P_{ij}(enrolled=1)}{1-P_{ij}(enrolled=1)}\right)=\tau_0+\overbrace{\underbrace{\Gamma_1 Sibcom_{ij}+\tau_2 male_{ij}+\Gamma_3 Sibcom_{ij}*male_{ij}+\tau_4 age_{ij}+u_j}_{\text{Hypotheses 1 and 2}}+\Gamma_5 Sibcom_{ij}*poor_j+\Gamma_6 sibcom_{ij}*poor_j*male_{ij}}^{\text{Hypothesis 3}}$$

Equation (1)

where $P_{ij}$(*enrolled*=1) is the probability of having education for the *i*th child in the *j*th household and $u_i$ is the individual household effect. The meaning of the rest of the variables has already been described. τ and Γ are the associated coefficient (vector) Recall that *Sibcom* could take different forms of sib composition. If *Sibcom* takes the form of four sibling categories, then *Sibcom* in equation (1) is a variable vector, containing three variables on sibling categories with one sibling category left out due to the collinearity with the household fixed characteristic of sib size. In our analysis we dropped the category of younger sister from the model.  And *Sibcom*poor* and *Sibcom*poor *male* are variable vectors too. Their associated Γs are coefficient vectors. If *Sibcom* takes the form of two dichotomy sibling categories, such as older siblings and younger siblings, *Sibcom* in equations (1) contains only one variable. So does *Sibcom*poor* and *Sibcom*poor *male*. Then associated Γs are coefficient scalars. Exp(τ) is the odds ratio measuring the factor of the change of odd in response to a change of one unit in the covariate.  (exp(τ)-1)*100% is the percent change of the odd of being *enrolled*.  To test hypotheses #1 and #2, we included the first six terms of equation (1).  We added two interaction terms when testing hypothesis #3 on sharper effects in poorest households. Negative and statistically significant  Γ and ($\Gamma+\Gamma_5$) would support the hypothesis among female and male children respectively.

In the second step we estimated the impact of sib composition on *maximum* achieved schooling with a linear regression model, conditional on *enrolled*=1.

$$maximum_{ij}(enrolled=1)=\overbrace{\underbrace{\beta_0+B_1Sibcom_{ij}+\beta_2male_{ij}+B_3Sibcom_{ij}*male_{ij}*+\beta_4age_{ij}+}_{\text{Hypotheses 1 and 2}}\gamma_j+B_5Sibcom_{ij}*poor_j+B_6Sibcom_{ij}*poor_j}^{\text{Hypothesis 3}}*male_{ij}$$

*Equation (2)*

In equation (2), *maxinum* is the maximal completed school grades among those who received education (*enrolled*=1); $\gamma_j$ is the *j*th household specific effect; β and B are the corresponding coefficient (vector).

We used linear regression models to assess the effect of sib composition on children's skills. All school-age children were included in the analysis, whether they had education or not. The model specification for skills was the same as the model specification used to estimate *maximum* schooling, except that we added *maximum* years of education as an additional control variable to remove the indirect impact of sib composition on skills though education attainment.

$$skill_{ij} = \overbrace{\underbrace{\alpha_0 + A_1 Sibcom_{ij} + \alpha_2 male_{ij} + A_3 Sibcom_{ij} * male_{ij} + \alpha_4 age_{ij} + \alpha_5 maximum + \lambda_j}_{\text{Hypotheses 1 and 2}} + A_6 Sibcom_{ij} * poor_j + A_7 Sibcom_{ij} * poor_j * male_{ij}}^{\text{Hypothesis 3}}$$

Equation (3)

We understand that reading *(literacy)*, *writing*, and fluency speaking *Spanish* are binary dependent variables and linear regression is not the most appropriate approach with those outcomes. However, our *ex-post* analysis suggests that most coefficients for academic skills in the linear models are not statistically significant and their significance level is generally consistent with the coefficients from the logit models. We used linear regressions to ease the interpretation of results because the coefficients could be interpreted as marginal changes in the probability of the child being able to write, read, or speak fluent Spanish.

One more issue regarding model specifications worth noticing is that fixed attributes of households, such as total number of siblings or household wealth could not be included in the model because we used regressions with household fixed effects. This is why some variables were dropped from the analysis and why results shown in the tables later differ slightly from what we describe above. For example, if we used four sibling categories in the regression, it would create perfect multi-collinearity with the household fixed characteristic of sib size. We have to drop one sibling category from the analysis. Additionally, the child's sex is also collinear with four sibling categories simply because the children's sex is determined if we have the information on four sibling categories for each child.  Therefore, we do not include the sex of children (*male*) and its associated interaction terms with sib compositions in the regression when *Sibcom* takes the form of four sibling categories.  In summary, if *Sibcom* in the equations represents the composition of four sibling categories, the variables of *male* and *male*Sibcom* are excluded from the model.

**The Tsimane': Education, sib composition, and resource constraints**

The Tsimane' are a native Amazonian society of farmers and foragers who live mainly in the department of Beni.  They number ~8,000 people and live in ~100 villages.  They have been in sporadic contact with Westerners since the early 1950s (Huanca, 2008).  Like many native Amazonian societies, Tsimane' practice hunting, fishing, plant foraging, and slash-and-burn farming.  Tsimane' live in small villages with an average of 19.32 households/village (SD=11.80).

A recent publication contains a description of the geographic setting, history, and ethnography of the Tsimane' (Huanca 2008). Recent publications also contain descriptions of the spread of modern schooling (Godoy et al. 2007) and the private returns to schooling and to academic and language skills (Godoy et al. 2005, 2007a; Reyes-García et al. 2008). Since we have covered much of the background material elsewhere, we limit the discussion of this section to three topics directly relevant to the main aim of this article: ***(i)*** description of the main forms and variation of modern human capital among children, ***(ii)*** sib composition, and ***(iii)*** resource constraints.

***(i)*** <u>Main forms and variation of modern human capital among children</u>. Protestant missionaries introduced the first schools in the Tsimane' territory during the 1950s. From their arrival until they left in 2008, missionaries trained Tsimane' to become teachers and produced free textbooks in Tsimane' for use in Tsimane' schools. Only during the last 1-2 years have Bolivians of mixed descent (known as mestizos) who are not Tsimane' started to teach in a few Tsimane' primary village schools, and only since 2005 have some of the larger villages started to have a middle school. Tsimane' teachers continue to instruct in the Tsimane' language in primary and in middle schools. To pursue a high-school education Tsimane' must go to towns.

Two points deserve stressing. First, because teaching in primary school takes place in Tsimane', one cannot assume that formal schooling and fluency in Spanish correlate highly. In the sample of children used for the analysis we found that the Pearson correlation coefficient of child *maximum* schooling and fluency speaking Spanish (2=fluent; 1=some fluency; 0=none or monolingual in Tsimane') was 0.54 (p=0.001). This provides one justification for including language skills as another form of modern human capital. Second, because missionaries set up the first schools during the 1950s and Tsimane' did not start attending school regularly until much later, one cannot estimate the association between sib composition and educational attainment across different cohorts.

At present, most Tsimane' villages have a public primary school which covers the first five grades. Classes take place during 200 days/year, from February until November, with a vacation of 2-3 weeks in June. In primary school, children learn academic topics in Tsimane', such geography, mathematics, reading, and writing, with Spanish taught as a subject.

***(ii)*** Sib composition. The 232 households with children <16 years of age averaged a total of 6.17 people/household (SD = 2.52), or 4.17 male adult equivalents/household (SD=1.72). Households with children had, on average, 3.05 females (SD=1.55) and 3.12 males (SD=1.62). Of the 6.17 people in a household, 3.81 (SD=2.18) were under the age of 16, evenly split between girls (mean/household = 1.86; SD=1.38) and boys (mean/household =1.94; SD=1.48).

The data suggests no sex bias in child survival or in anthropometric indicators of nutritional status. For example, during the 2007 survey we asked females >16 years of age to report the total number of offspring dead or alive born to them and the total number of those offspring still alive. We computed a survival ratio for female and male offspring. The survival ratio for girls was estimated by dividing the number of living girls born to a woman by the total number of births (alive or dead) of girls born to the woman. Similar steps were followed to compute a survival ratio for boys. We found survival ratios for female and male offspring of 84.71% and 81.69% (p=0.205), suggesting no statistically significant difference in survival between girls and boys. This result matches with an earlier study in which we tested for girl-boy disparities in anthropometric indicators of short and long-run nutritional status and found no significant difference (Godoy et al. 2006).

***(iii)***. Resource constraints. Measuring income in a highly autarkic society is hard in part because much of people's income comes through consumption from their own production. In an earlier article (Godoy et al. 2007b) we presented estimates of income with adjustments for the following: *(a)* household male adult equivalents or head count, *(b)* value of consumption from own production, *(c)* inter-household transfers, and *(d)* purchasing power parity. We found that depending on the adjustments made, daily income reached US$2.35-3.52 per person or per male adult equivalent, above the international poverty line of US$1-2/person, on a par with the income in the rest of all of Bolivia (urban and rural), and three times higher than the income in the rest of rural Bolivia. Though low, income is growing; during 2002-2006, the real value of monetary income increased by 5.3%/year (Godoy et al. 2009).

**Results**

Main. Table 1 summarizes the derived coefficients from the regression with *Sibcom* taking the form of four sibling categories (Appendix 1). The results of Table 1 suggest that sib composition has significant direct and indirect effects on a child's modern human capital. When using the two schooling variables as outcomes, we see that all the coefficients bear a negative sign, suggesting that older siblings divert resources away from younger siblings. Of the eight coefficients for older sisters and for older brothers that capture their direct effects on child schooling (columns [a]-[b], Table 1), three coefficients measuring the impact of older brothers were statistically significant. Holding constant sib composition, an additional older brother was associated with a 72% reduction in the odds that a younger sister would obtain any schooling (row IIa, column a; p=0.009). Older brothers also imposed costs on younger brother (row IIb, columns a-b). One more older brother was associated with a 75% reduction in the odds that a younger brother would have any schooling (row IIb, column a; p=0.001). Another older brother reduced by 0.43 years the maximum school achievement of a younger brother (row IIb, column b; p=0.001). The consistent negative coefficients for older sisters may suggest the possible adverse impact of older sisters on younger siblings' education. Some of the coefficients for older sisters are marginally significant at the 0.10 level. For example, holding sib size constant, an additional older sister may reduce the maximum school attainment of a younger brother by 0.23 years (row IIb, column b; p=0.100).

INSERT TABLE 1 ABOUT HERE

We found no direct, consistent significant impact of sib composition on academic skills (column c-f), with one exception. An additional old brother was associated with a 13% lower probability of being able to write after conditioning for maximum education. However, row III suggests that *maximum* schooling has a positive and significant association with all the skills except for fluency speaking Spanish. Having one more year of schooling was associated with an improvement of 0. 30 points in the math test (range: 0-4)(p<0.001) and with an increase in the child's probability of reading and writing by 7% (p=0.006) and 10% (p<0.001). As an older brother affects the probability of being educated and the number of years of education received, having an additional older brother affects the child's math, reading, and writing skills indirectly via schooling.

As shown in Table 1, older brothers reduce the school attainment of younger siblings, and older sisters seem to have a similar albeit less pronounced impact on siblings' education. But we did not find that older sisters had consistent and significant impact on skills, except for writing (column f). To explore further the effects of older siblings on the modern human capital of younger siblings, we re-estimated the regressions of Table 1, but combined older brothers and older sisters. Instead of the three variables for the three types of siblings, we put one variable: the total number of older siblings (sisters plus brothers). Because the variable for the child's sex, *male*, is not perfectly correlated with the total number of older siblings, we included it and its interaction with number of older siblings in the regression (Table 2).

INSERT TABLE 2 ABOUT HERE

The results in Table 2 suggest statistically significant impacts of older siblings on younger sibling's schooling. Holding household size constant, an additional older sibling was associated with a reduction of 52% in the odds of obtaining any education (row I, column a) (p=0.010) with 0.25 fewer years (p=0.043) of completed school education (row I, column b) among younger sisters. The interaction term, *older sibling***male,* in row III (columns a-b) suggests that another older sibling had the same effect on schooling outcomes of younger sisters or younger brothers. The results in row I of columns c-f suggest no direct impact of older siblings on the skills of younger sisters. However, one more older sibling harms more the skills of younger brothers than the skills of younger sisters. For example, the coefficients of row III, columns c, e-f imply that one more older sibling reduces by 0.11 points the math score of a younger brother compared with the math score of a younger sister (column c). An additional older sibling reduces by 3.3% and by 3.6% more the probability that a younger brother is literate (row III, column e) or can write (row III, column f) compared with a younger sister..

The coefficients for *male* in Table 2 (row II) suggest that brothers have better math, reading, and writing skills than their sisters. By including the main effect of *male* we assume that higher indices of modern human capital among boys compared with girls are independent from the influence of older siblings. To relax this assumption and assume that human capital differences between males and females reflect the impact of older siblings, we re-estimated the model by excluding the variable *male*. To save space, we do not show the regression results, but those results suggest that having another older sibling has the same effect on the modern human capital of younger brothers or younger sisters less; all the coefficients for the interaction term of *older sibling***male* were statistically insignificant at the 0.05 confidence interval.

<u>Interaction with wealth and income</u>. Recall that we expect the effects of sib composition to be stronger among households most constrained in resources. Since Table 1-2 suggest that it is mainly older siblings, particular older brothers, who affect the modern human capital of younger siblings, and using two sibling categories (*older siblings* vs. younger siblings) could reduce the computation work, in the analysis that follows we build on Table 2 by only including the total number of older siblings.

In Tables 3A we show regression results with two new interactions of *older siblings*poor* and *older siblings*poor*male*, using parental wealth (*poor*) as the measurement of resource constraints.

INSERT TABLE 3A ABOUT HERE

In section A of Table 3a, the coefficient for the variable *number of older sibling* captures the impact of an additional older sibling on the modern human capital of a younger sister in a rich household. The coefficient for the double interaction variable *older sibling*poor* captures the differential impact of an additional older sibling on the modern human capital of a younger sister between poor and rich families. The coefficient for the double interaction term *older sibling*male* captures the differential impact of an additional older sibling on the modern human capital of a younger brother compared with a younger sister in a rich household. The coefficient for the triple interaction variable, *older sibling*male*poor,* captures the additional impact of an additional older sibling on the modern human capital of younger brothers in a poor household. Section B of Table 3a shows the linear combinations of the coefficients from section A to estimate the effects of older siblings on the modern human capital of younger sisters and younger brothers. Section C of Table 3a contains estimates of the differential impact of an additional older sibling on the modern human capital of younger siblings between rich and poor families.

The results of section B in Table 3A show the impact of an additional older sibling on the schooling of younger siblings, whether in poor or in rich families. Of the eight coefficients measuring the effect of older siblings on the youngers' school enrollment (column a) and maximum completed education (column b) in poor (rows Ib, IIb) and in rich families (Ia, IIa), seven are statistically significant, and all bear negative signs. An additional older sibling was associated with 47% (p=0.034) reduction in the odds that a younger sister in a rich household would obtain any education, in comparison with a sharper 73% (p=0.018) reduction in the odds that a younger sister in a poor household would obtain any education. However, the difference (47% in rich household vs. 73% in poor household) was not statistically significant (p=0.222). An additional older or sibling lowered by 62% the odds (p=0.027) that a younger brother in a poor household would have any education, but an additional older sibling lowered by only 49% the odds (p=0.045) that that a younger brother in a rich household would have any education. The difference was not significant (P=0.550).

Having more older siblings lowered by 0.26 years (p=0.048) the maximum educational attainment of a younger sister in a rich household, but we did not find statistically significant effect of older siblings on younger sisters' maximal education in poor households. An additional older siblings lowered by 0.31 years (p=0.019) the maximum educational attainment of a younger brother in a rich household compared with 0.18 and 0.32(p=0.049) years of the counterpart in a poor household.

Contrary to our expectations (hypothesis #3) that the addition of a sibling would produce sharper effects on the modern human capital of children in poorer households, four of the 12 coefficients in section C of Table 3A with statistical significance suggest that the adverse effect, if any, of having additional older siblings is ameliorated in a poor household compared with a rich household. But this does not apply to schooling, and none of the coefficients on schooling in section C of Table 3A was statistically significant. This suggest that the adverse effect of having an additional older siblings on the likelihood that a child enrolls in school or on the maximum school attainment of the child applies to the entire sample irrespective of the household's relative wealth. The insignificant coefficients for speaking *Spanish* suggest that an older siblings' adverse effect on a younger siblings' ability to speak Spanish does not depend on a household's relative wealth.

In Table 3B we compute the effect of sib composition on a child's modern human capital using temporary income instead of wealth. The results of Table 3B agree with the results of Table 3A that having an additional elder sibling was associated with a lower probability of being enrolled in school and with a lower level of education completed and an additional older sibling did not directly affect younger siblings' learning skills. But unlike Table 3A, we did not find any differential impact of older siblings between poor and rich households in section C.

In sum, after we included the interaction of sib composition with a household's relative socioeconomic status measured through wealth or through temporary income, and its further interaction with a child's sex, we found that elder siblings harmed the accumulation of modern human capital of the child, lowering the probability of being enrolled in school and reducing the level of completed school education. Contrary to our expectations, the effects do not gain salience among poorer households.

<u>Extensions</u>. We extend the analysis in two ways. First, we examine whether having siblings of the opposite sex matter. Conley (2000, 2004) reviews research suggesting that it may not be older or younger brothers or sisters who affect educational attainment, but siblings of the opposite sex, irrespective of the child's sex. Conley argued that the number of siblings of the opposite sex might erode most the educational

attainment of children because children of the opposite sex proxy for unsatisfied needs specific to each sex (Steelman et al. 2002). The hypothesis is known as the sex minority hypothesis. Second, we examine whether having any sisters matters. At least in industrial societies (Bucher and Case 1994; Kaestner 1997; Parish and Willis 1993) and in South Africa and Tanzania (Morduch 2000) researchers have found some evidence suggesting that having sister may affect most school attainment.

Table 4 contains the results of the additional analysis. Section A suggests that the number of siblings of the opposite sex bears no significant association with the six indicators of modern human capital (row I; section A; Table 4). Nor did we find significant effects in the interaction term of the child's sex (*male*=1, female=0) and the number of sibling of the opposite sex (row II; section A; Table 4).

INSERT TABLE 4 ABOUT HERE

The results in section B of Table 4 suggests that unlike industrial nations and some poor nations, having any sisters has no systematic direct significant effect on indicators of modern human capital (row I, section B, Table 4). None of the coefficients quantifying the effect of having any sisters shows statistical significance.

**Discussion and conclusions**

We had hypothesized that the age and sex composition of sibling would have ambiguous effects on a child's modern human capital (hypothesis #1 and 2). This hypothesis was partially supported because most of the coefficients capturing the effects of sib composition on skills were insignificant and had inconsistent signs. Nevertheless, we found a consistent adverse effect of having an additional older sibling on the probability that a younger sibling would enroll in school or on the maximum years of school attainment of a younger sibling. The results are consistent with findings from studies by Behrman and Taubman (1986) and Black et l. (2005), who found that older children have higher school attainment. Unlike skills that children can learn from their sisters and brothers even with limited resources, formal school education is more likely to be dominated by resource constraints. Our major finding is that older siblings, particular old brothers, impair younger siblings' schooling and that an additional older sibling lowers by 0.30 (Table 2) the number of years of education completed by a younger sibling. Compared with the effect size from the studies reviewed, the effect size from our study is slightly larger. Recall that we analyze children's education level only when they have some education. The marginal effect on educational attainment in the whole sample could be smaller given the average low level of maximum completed education for those attending school (mean = 2 .02, median = 2.00, SD= 1.22) and low enrollment rate (57%).

We also hypothesized a sharper effect of sib composition among poorer household (hypothesis #3). Our study did not confirm this hypothesis; the effect of sib composition on human capital did not differ between poor and rich households. Perhaps, widespread sharing and reciprocity between households in a village linked by bonds of blood and marriage ease some of the resource constraints of poorer households. Like other native Amazonian societies, Tsimane' practice preferential cross-cousin marriage, meaning that a man marries his mother's brother's daughter or his father's sister's son. When practiced over many generations in a small-scale society of only ~8,000 people, preferential cross-cousin marriage and tight endogamy within the ethnic group produces a thick and wide network of kin, all linked by bonds of marriage and blood. Indeed, in such a setting society is family writ large. In several publications we have documented the pervasiveness of sharing and reciprocity between households in food, drinks, and labor help (Reyes-García et al. 2009; Godoy et al. 2007; Brabec et al. 2006.

Besides the finding that another older sibling harms the human capital of younger sibling by lowering the probability of enrolling in school and by reducing the number of years of completed education, we find that by affecting exposure to schooling, an additional older sibling indirectly affects the academic and language skills of younger siblings.

To explain the finding that older children tend to have higher school achievement than younger children, economists have measured parental time allocated to children and found that the time spent per child decreases as the number of children increases and older children have "some periods, particular during presumably critical early years, when he or she has less competition for mother's time than do younger siblings" (Black et al. 2005; Hill and Stafford 1974; Leibowitz 1974) Further, the theory of human capital suggests that resources may be less available for younger children because older children are likely to deplete household savings (Black et al. 2005). Two additional reasons specific to Tsimane' society might help explain why the age composition of siblings has a stronger effect in the modern human capital of children than the sex composition of sibling.

First, modern forms of human capital yield positive, large private returns to adults and parents are well aware of these returns. Using five years of annual panel data

(2002-2006) and controlling for individual and for community fixed effects and a wide range of other covariates, we found pooled (females and males) private real (i.e., inflation adjusted) returns to schooling among adults of 4.70% (p=0.04), with slightly higher rates for men (5.22%; p=0.088) than for women (4.12%; p=0.234). In earlier studies using cross-sectional data we found that math skills were associated with 13.5% higher monetary income among adults (Godoy et al. 2005). We have also found that Tsimane' adults who can speak fluent Spanish earned 36.9-46.9% more monetary income than monolingual speakers of Tsimane', even after controlling for education and for math skills (Godoy et al. 2007a). We have also shown elsewhere (Kirby et al. 2002) that Tsimane' have high rates of private time preference, impulsivity, or myopia. Combined, all this evidence would suggest that parents have incentives to invest in modern human capital of their children. But to obtain faster returns, parents will tend to invest more in older offspring and divert resources that would have been allocated to younger offspring.

Second, the low opportunity costs of children's time spent in class ameliorate the possible concerns of parents of investing in older [do a check and replace of elder] siblings. Parents might keep the older child out of school because parents do not want to give up the help they receive from their older children when older children attend school. Older children work as caretakers and contribute to the household economy by fishing, farming, and by collecting feral goods from the forest, such as firewood, building material, and edible wild plants (Martínez Rodríguez 2009). Since school takes place only during weekday mornings, and only during 200 days in a year, Tsimane' parents do not forgo all their children's help when children go to school. Such school schedule may mitigate parents' concerns of lack of hands when needed. The low opportunity cost of attending school combined with the benefits of being an older child, such as having preferential access to parental resources, help explain why we observe a larger effect of older siblings on the modern human capital of children.

Unlike some studies from industrial nations, we found no support for the sex minority hypothesis or for the hypothesis that having any sister matters. The finding of no adverse effects from sisters probably has to do with the equality between girls and boys in their contribution to the household economy and to the absence of girl-boy differences in many indicators of well being, discussed earlier.

The study contributes to the literature linking sib composition with child outcomes in three ways. First, it underscores the importance of obtaining separate measures of the number of older and younger sisters and brothers to identify with precision the type of sibling that might matter most. Second, the study underscores the importance of a cross-cultural approach (particularly in rural areas of poor nations) to better understand the conditions under which sib composition might matter. Last, the study underscores the importance of using different indicators of modern human capital to ensure results do not hinge on definitions of modern human capital. For instance, we found some evidence that having an older sibling was associated with years of completed schooling and enrollment or writing, but not with other indicators of modern human capital.

ACKNOWLEDGEMENTS

The Cultural and Physical Anthropology Programs of NSF provided funding for the research. D. Eisenberg was supported by an NSF Graduate Research Fellowship. The IRB for research with human subjects of Northwestern University and Brandeis University, and the Great Tsimane' Council approved the study. Before enrollment in the study we obtained assent from participants.

TABLE 1. Associations between *(1)* modern human capital (schooling and skills; outcome variables) and *(2)* sib composition (4 categories) among Tsimane' children ≤16 years of age surveyed in 2007: Summary of regressions with household fixed effects[1]

| Effects (Coefficients) | | Outcome variables | | | | | |
|---|---|---|---|---|---|---|---|
| | | Schooling | | Skills | | | |
| | | *Enrolled* | *Maximum* | *Math* | *Spanish* | *Literacy* | *Writing* |
| | | ***[a]*** | ***[b]*** | ***[c]*** | ***[d]*** | ***[e]*** | ***[f]*** |
| I. Of another older sister | On human capital of | | | | | | |
| | a, Younger sisters | -0.199 | -0.099 | -0.043 | -0.042 | -0.001 | -0.04 |
| | b. Younger brothers | -0.292 | -0.232 | 0.187 | -0.016 | 0.030 | 0.037 |
| II. Of another older brother | | | | | | | |
| | a, Younger sisters | **-1.290**** | -0.295 | -0.232 | -0.049 | -0.041 | **-0.128**** |
| | b. Younger brothers | **-1.383**** | **-0.428**** | -0.003 | -0.023 | -0.009 | -0.051 |
| III. Of maximum | | | | **0.302**** | 0.053 | **0.069**** | **0.106**** |
| Observations | | 541 | 308 | 482 | 485 | 482 | 473 |
| Regression type | | Logit | OLS | OLS | OLS | OLS | OLS |

[1] Regressions include robust standard errors, clustering by household, and constant and person's age (not shown). *p ≤ 0.05, ** ≤ 0.01. Appendixes 1-2 contains definition of variables and Appendix 3, supporting on-line material, contains the original results of regression model for each outcome.

TABLE 2. Associations between *(1)* modern human capital (schooling and skills; outcome variables) and *(2)* sib composition (two categories) among Tsimane' children ≤ 16 years of age surveyed in 2007: Results of models with household fixed effects[1]

| Covariates | Outcome variables | | | | | |
|---|---|---|---|---|---|---|
| | Schooling | | Skills | | | |
| | *Enrolled* | *Maximum* | *Math* | *Spanish* | *Literacy* | *Writing* |
| | ***[a]*** | ***[b]*** | ***[c]*** | ***[d]*** | ***[e]*** | ***[f]*** |
| I. Number of older siblings | **-0.728**** | **-0.247*** | 0.008 | -0.037 | 0.002 | -0.035 |
| II. Male: boy=1; girl=0 | 0.575 | 0.312 | **0.599**** | -0.002 | **0.183**** | **0.218**** |
| III. Older sibling*male | -0.029 | -0.075 | **-0.114*** | 0.009 | **-0.033*** | **-0.036*** |
| IV. Maximum | | | **0.282**** | 0.052 | **0.063*** | **0.102**** |
| Observations | 541 | 308 | 482 | 485 | 482 | 473 |

[1] Same notes as Table 1.

TABLE 3A. Associations between *(1)* modern human capital (schooling and skills; outcome variables) and *(2)* sib composition interacted with parental wealth among Tsimane' children ≤16 years of age surveyed in 2007: Results of models with household fixed effects[1]

| | Outcome variables | | | | | |
|---|---|---|---|---|---|---|
| | Schooling | | Skills | | | |
| | *Enrolled* | *Maximum* | *Math* | *Spanish* | *Literacy* | *Writing* |
| | *[a]* | *[b]* | *[c]* | *[d]* | *[e]* | *[f]* |
| **A. Coefficients from regressions** | | | | | | |
| I. Number of older siblings | **-0.641*** | **-0.256*** | -0.091 | -0.046 | -0.017 | -0.05 |
| II. Older sibling*poor | -0.681 | 0.074 | **0.321**** | 0.043 | **0.068*** | **0.053*** |
| III. Older sibling*male | -0.028 | -0.052 | -0.098 | 0.021 | -0.025 | -0.031 |
| IV. Older sibling*male*poor | 0.392 | -0.081 | -0.059 | **-0.048*** | **-0.031*** | -0.018 |
| V. Male: boy = 1; girl=0 | 0.222 | 0.314 | **0.608**** | 0.016 | **0.193**** | **0.221**** |
| VI. Maximal education | | | **0.272**** | 0.051 | **0.061*** | **0.100**** |
| **B. Effect of older siblings** | | | | | | |
| I. On younger sister | | | | | | |
| a. In rich family | **-0.641*** | **-0.256*** | -0.091 | -0.046 | -0.017 | -0.05 |
| b. In poor family | **-1.322*** | -0.182 | **0.230*** | -0.003 | 0.051 | 0.003 |
| II. On younger brothers | | | | | | |
| a. In rich family | **-0.669*** | **-0.308*** | **-0.189*** | -0.025 | -0.042 | **-0.081**** |
| b. In poor family | **-0.958*** | **-0.315*** | 0.073 | -0.030 | -0.005 | -0.046 |
| **C. Differential effect of an older siblings in poor household compared with rich household** | | | | | | |
| I. On younger sisters | -0.681 | 0.074 | **0.321**** | 0.043 | **0.068*** | **0.053*** |
| II. On younger brothers | -0.289 | -0.007 | **0.262**** | -0.005 | 0.037 | 0.035 |
| Observations | 541 | 308 | 482 | 485 | 482 | 473 |

[1] Same notes as Table 1, except *poor* = 1 if household is in the bottom half of the distribution of parental household wealth, and zero otherwise. See Appendix 2 for definition of wealth.

TABLE 3B. Associations between *(1)* modern human capital (schooling and skills; outcome variables) and *(2)* sib composition interacted with parental <u>annual income</u> among Tsimane' children ≤16 years of age surveyed in 2007: Results of models with household fixed effects[1.]

| | Outcome variables | | | | | |
|---|---|---|---|---|---|---|
| | Schooling | | Skills | | | |
| | *Enrolled* | *Maximum* | *Math* | *Spanish* | *Literacy* | *Writing* |
| | ***[a]*** | ***[b]*** | ***[c]*** | ***[d]*** | ***[e]*** | ***[f]*** |
| **A. Coefficients from regressions** | | | | | | |
| I. Number of older siblings | -0.549 | **-0.297*** | 0.050 | -0.057 | 0.001 | -0.035 |
| II. Older sibling*poor | -0.241 | 0.121 | -0.100 | 0.045 | 0.004 | 0.001 |
| III. Older sibling*male | -0.095 | -0.079 | **-0.132*** | 0.018 | -0.034 | -0.037 |
| IV. Older sibling*male*poor | 0.162 | -0.002 | 0.036 | -0.018 | 0.003 | 0.003 |
| V. Male: boy = 1; girl=0 | 0.555 | 0.323 | **0.604**** | -0.004 | **0.183**** | **0.218**** |
| VI. Maximal education | | | **0.283***** | 0.051 | **0.063*** | **0.102***** |
| **B. Effect of older siblings** | | | | | | |
| I. On younger sister | | | | | | |
| a. In rich family | -0.549 | **-0.297*** | 0.050 | -0.057 | 0.001 | -0.035 |
| b. In poor family | **-0.790*** | -0.176 | -0.050 | -0.012 | 0.005 | -0.034 |
| II. On younger brothers | | | | | | |
| a. In rich family | -0.644 | **-0.376**** | -0.082 | -0.039 | -0.033 | **-0.072*** |
| b. In poor family | **-0.723*** | **-0.257*** | -0.146 | -0.012 | -0.026 | **-0.068*** |
| **C. Differential effect of an older siblings in poor household compared with rich household** | | | | | | |
| I. On younger sisters | -0.241 | 0.121 | -0.100 | 0.045 | 0.004 | 0.001 |
| II. On younger brothers | -0.079 | 0.119 | -0.064 | 0.027 | 0.007 | 0.004 |
| Observations | 541 | 308 | 482 | 485 | 482 | 473 |

[1] Same notes as Table 1, except *poor* = 1 if household is in the bottom half of the distribution of forest area cleared in the sample, and zero otherwise. Income = area of old-growth forest and fallow forest cleared for farming in previous year, divided by male adult equivalents in the household.

Table 4. Associations between *(1)* modern human capital (schooling and skills; outcome variables) and *(2)* siblings of opposite sex and having sisters among Tsimane' children ≤ 16 years of age surveyed in 2007: Results of models with household fixed effects[1.]

| Covariates: | Outcome variables | | | | | |
|---|---|---|---|---|---|---|
| | Schooling | | Skills | | | |
| | *Enrolled* | *Maximum* | *Math* | *Spanish* | *Literacy* | *Writing* |
| | ***[a]*** | ***[b]*** | ***[c]*** | ***[d]*** | ***[e]*** | ***[f]*** |
| **A. Children of opposite sex(sex minority hypothesis)** | | | | | | |
| I. # siblings opposite sex | -0.096 | 0.035 | 0.003 | -0.035 | -0.002 | -0.001 |
| II. Siblings opposite sex*male | 0.292 | -0.027 | -0.012 | -0.003 | -0.036 | 0.031 |
| III. Male | -0.558 | 0.166 | 0.266 | 0.011 | 0.195 | -0.01 |
| IV. Maximum | | | **0.300**** | **0.061*** | **0.071**** | **0.110**** |
| **B. Having any sisters** | | | | | | |
| I. Any sister | 0.931 | -0.098 | -0.151 | 0.155 | 0.019 | -0.153 |
| II. Male | 0.422 | 0.066 | 0.239* | 0.005 | 0.072 | **0.110**** |
| III. Maximum | | | **0.300**** | **0.055*** | **0.068**** | **0.113**** |
| Observations | 541 | 308 | 482 | 485 | 482 | 473 |

[1] Same notes as Table 1, except *any sister* =1 if person has a sister, and zero otherwise.

Appendix 1: Definition and description of outcome variables

| **Outcome variable** | **Definition and description** |
|---|---|
| Education (information supplied by child's principal caretaker): | |
| *Enrolled* | Child ever enrolled in school. Yes=1; no=0 |
| *Maximum* | Maximum school grade attained. |
| Skills (measured through tests given by surveyor or assessed by surveyor): | |
| *Math* | Score in math test in which surveyor asked child to add, subtract, multiply, and divide numbers given by the surveyor. Each of the four questions shown in a different 3x5 card. Range of score: 0-4. |
| *Spanish* | Fluency speaking Spanish as determined by surveyor. 1=child speaks some Spanish or is fluent in Spanish; 0=child is monolingual in Tsimane' |
| *Literacy* | 1=child could read simple sentence in Spanish given by translator. Sentence written in large letters in white paper and shown to child in daylight. 0=child could not read. |
| *Writing* | 1=child able to sign her or his name on a white paper given by translator. 0=child unable to sign name. |

Appendix 2: Wealth and male adult equivalents

Wealth. We measured wealth by first adding the nominal monetary value of 22 physical assets owned by the female and the male heads of the households: *(1)* five traditional physical assets central to their subsistence (e.g., canoes, bows), *(2)* 13 modern physical assets that capture some luxury goods (e.g., radios) and modern technologies for agricultural production (e.g., cutlasses), and *(3)* four domesticated animals (e.g., chickens, ducks) that contribute to consumption and buffer people against adverse mishaps. Based on ethnographic knowledge of the Tsimane' (Huanca, 2008; Martínez-Rodríguez, 2009), we selected physical assets that captured wealth differences in the entire sample, and between females and males. For instance, the poorest people own bows, arrows, and small domesticated animals (e.g., chickens), but wealthier people are more likely to own large domesticated animals (e.g., cattle) and expensive industrial goods (e.g., guns). Among the assets measured, we included assets that females own (e.g., bags, pots) and assets that males own (e.g., cattle, guns). We multiplied the quantity of each asset owned times the selling price of the asset in the village to estimate the nominal monetary value of the asset, and then added the value of the different assets to arrive at the nominal value of total wealth for each of the two household heads. We then added the values of wealth for the two household heads, and divided the total by the number of male adult equivalents.

Male adult equivalents. Male-adult equivalent refers to the notion that people differ in their energy needs as a function of their sex and age, so a child might represent a fraction of an adult in energy needs. We calculated the energy requirements using the most recent FAO-WHO protocol (Godoy et al. 2007b). The FAO-WHO method determines energy needs based on body size and on typical activity levels. This has become the preferred approach for determining food and energy requirements since dietary recalls do not accurately reflect variation in food and energy requirements. The reference category for estimating adult equivalents was a male 18–59 years of age.

Appendix 3. Associations between *(1)* modern human capital (schooling and skills; outcome variables) and *(2)* sib composition (4 categories) among Tsimane' children ≤16 years of age surveyed in 2007: supplementing to Table 1[1].

| Covariate: | Outcome variables | | | | | |
|---|---|---|---|---|---|---|
| | Schooling | | Skills | | | |
| | *Enrolled* | *Maximum* | *Math* | *Spanish* | *Literacy* | *Writing* |
| | ***[a]*** | ***[b]*** | ***[c]*** | ***[d]*** | ***[e]*** | ***[f]*** |
| Younger sister (reference) | | | | | | |
| Older sister | -0.199 | -0.099 | -0.043 | -0.042 | -0.001 | -0.040 |
| Younger brother | 0.093 | 0.133 | -0.230* | -0.026 | -0.031 | -0.077 |
| Older brother | -1.290** | -0.295 | -0.232 | -0.049 | -0.041 | -0.128** |
| Age | 0.474** | 0.108 | 0.160** | 0.056** | 0.038** | 0.033** |
| maximum | - | - | 0.302** | 0.053 | 0.069** | 0.106** |
| Constant | - | 1.131 | -0.563 | -0.155 | -0.209 | 0.134 |

[1] Regressions include robust standard errors, clustering by household, and constant and person's age (not shown). *$p \leq 0.05$, ** $\leq 0.01$

Literature cited

Behrman, Jere R. and Taubman, Paul. 1986. Birth Order, Schooling and Earnings. Journal of Labor Economics, 4 (3): 121-145.

Black, Sandra E.; Paul. J. Devereux, and Kjell G. Salvanes. 2005. The more the merrier? The effect of family size and birth order on children's education. Quarterly Journal of Economics 120:2:669-700.

Brabec, M., R. Godoy, V. Reyes-García, W.R. Leonard. 2006. BMI, income, and social capital in a pre-industrial society of the Bolivian Amazon: Interaction between relative and community effects. American Journal of Human Biology 19:459-474.

Buchmann, Claudia. 2000. Family Structure, Parental Perceptions, and Child Labor in Kenya: What Factors Determine Who is Enrolled in School?. Social Forces. 78(4):1349-1378.

Butcher, Kristin and Case, Anne. 1994. The Effect of Sibling Sex Composition on Women's Education and Earnings. The Quarterly Journal of Economics. 109(3): 531-563.

Conley, Dalton. 2000. Sib Sex Composition: Effects on Educational Attainment. Social Science Research. 29:441–457.

Conley, Dalton. 2004. <u>The Pecking Oder: Which Siblings Succeed and Why</u>. New York: Panthan books.

Cyrus Chu, C., Xie, Yu and Yu, Ruoh-rong. 2007. Effects of Sib Structure Revisited: Evidence from Intrafamily Resource Transfer in Taiwan. Sociology of Education. 80(*2*):91–113.

Dammert, Ana. 2010. Siblings, Child Labor, and Schooling in Nicaragua and Guatemala. Journal of Population Economics. 23:199–224.

Dayioğlu, Meltem, Kirdar, Murat and Tansel, Aysit. 2009. Impact of Sib Size, Birth Order and Sex Composition on School Enrolment in Urban Turkey. Oxford Bulletin Of Economics And Statistics. 71(*3)*:399-426

Downey, Douglas. 2001. Number of Siblings and Intellectual Development: The Resource Dilution Explanation. American Psychologist. 56(*6/7*):497-504 .

Guo, Guang and VanWey, Leah. 1999. Sib Size and Intellectual Development: Is the Relationship Causal? . American Sociological Review. 64(*2*):169-187.

Floyd, B. 2005. Heights and weights of DA-AN boys: did sisters really make a difference?. Journal of Biosocial Sciences. 37:287-300.

Godoy, Ricardo, D. Karlan, S. Rabindran, and T. Huanca. 2005. Do modern forms of human capital matter in primitive economies? Comparative evidence from Bolivia. Economics of Education Review. 24:1:45-53.

Godoy, Ricardo, Victoria Reyes-García, Tomás Huanca, William R. Leonard, Thomas McDade Susan Tanner, Vincent Vadez. Why do mothers favor girls and fathers boys? A hypothesis and test of intra-household girl-boy investment disparity. 2006. Human Nature 17:2:169-189.

Godoy, Ricardo, C. Seyfried, V. Reyes-García, T. Huanca, W. R. Leonard, T. McDade, S. Tanner, V. Vadez. 2007. Schooling's contribution to social capital: A study from a native Amazonian society in Bolivia. Comparative Education 43:1:137-163.

Godoy, Ricardo, Victoria Reyes-García, William R. Leonard, Tomás Huanca, Thomas McDade, Vincent Vadez, Susan Tanner. 2007a. Language skills and earnings: Evidence from a pre-industrial economy in the Bolivian Amazon. Economics of Education Review. 26:3:349-360.

Godoy, Ricardo, V. Reyes-García, W.R. Leonard, T. Huanca, T. McDade, V. Vadez, S. Tanner, and C. Seyfried. 2007b. On the measure of income and the economic unimportance of social capital. Evidence from a native Amazonian society of farmers and foragers. Journal of Anthropological Research 63:2:239-260.

Godoy, Ricardo, Victoria Reyes-García, Clarence C. Gravlee, Tomás Huanca, William R. Leonard, Thomas W. McDade, Susan Tanner, and the TAPS Bolivia Study Team. 2009. Moving beyond a snapshot to understand changes in the well-being of native Amazonians: Panel evidence (2002-2006) from Bolivia. Current Anthropology 50:4:563-573.

Hauser, Robert and Kuo, Daphne. 1998. Does the Gender Composition of Sibs Affect Women's Educational Attainment? 33(*3*):644-657.

Heckman, James J. 1976. The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models, Annals of Economic Social Measurement. 5(4): 475–492.

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

Kaestner, Robert. 1997. Are Brothers Really Better? Sibling Sex Composition and Educational Achievement Revisited. The Journal of Human Resources. 32(2): 250-284.

Kris N. Kirby, Ricardo Godoy, Victoria Reyes-García, et al. Correlates of delay-discount rates: Evidence from Tsimane' Amerindians of the Bolivian rain forest. Journal of Economic Psychology 23:291-316. 2002.

Kuo, Daphne and Hauser, Robert. 1997. How Does Size of Sib Matter? Family Configuration and Family Effects on Educational Attainment. Social Science Research. 26:69–94

Leonard, William R. and Ricardo Godoy. 2008. Tsimane' Amazonian Panel Study (TAPS): The first 5 years (2002-2006) of socioeconomic, demographic, and anthropometric data available to the public. Economics and Human Biology 6:2:299-301.

Martínez Rodríguez, Maria Ruth. 2009. Ethnobotanical knowledge acquisition among Tsimane' children in the Bolivian Amazon. PhD dissertation, department of anthropology, U of Georgia, Athens, Georgia.

Morduch, Jonathan. 2000. Sibling Rivalry in Africa. The American Economic Review. 90(*2*):405- 409.

Parish, William and Robert, Willis. 1993. Daughters, education, and family budgets Taiwan experiences. The Journal of Human Resources. 28(*4*):863-898.

Reyes-García, Victoria, T. McDade; V. Vadez; T. Huanca; W. R. Leonard; S. Tanner; R. Godoy. 2008. Non-market returns to traditional human capital. Journal of Development Studies 44:2:217-232.

Reyes-García, Victoria, R. Godoy, Vincent Vadez, Isabel Ruiz-Mallen, Tomás Huanca, William R. Leonard, Thomas W. McDade, Susan Tanner, and TAPS Bolivia Study Team. 2009. The pay-offs to sociality: Do solitary and social leisure related to happiness. Human Nature 20:431-446.

Rodgers, Joseph Lee, H. Harrington Cleveland, Edwin van den Oord, and David C. Rower. 2000. Resolving the debate over birth order, family size, and intelligence. American Psychologist 55:6:599-612.

Smith, Thomas. 1990. Academic Achievement and Teaching Younger Siblings. Social Psychology Quarterly. 53(*4*):352-363.

Steelman, Lala, Powell, Brian, Werum, Regina and Carter, Scott. 2002. Reconsidering The Effects Of Sibling Configuration: Recent Advances And Challenges. Annual Review of Sociology. 28:243–69.

Vadez, Vincent, Victoria Reyes-García, Ricardo Godoy, et al. 2003. Validity of self-reports to measure deforestation: Evidence from the Bolivian lowlands. Field Methods 15:3:289-304.

Van Eijck, Koen and de Graaf, Paul. 1995. The effects of family structure on the educational attainment of siblings in Hungary. European Sociological Review. 11(*3*):273-292.

Wei, Hsin Yu and Kuo, Hsien Su. 2006. Gender, Sib Structure, and Educational Inequality in Taiwan: Son Preference Revisited. Journal of Marriage and Family. 68:1057–1068.

Widmer, Eric, and Weiss, Christopher. 2000. Do older siblings make a difference? The effects of older sibling support and older sibling adjustment on the adjustment of socially disadvantaged adolescents. Journal of Research on Adolescence, 10(*1*):1-27.

Zajonc, Robert and Mullally, Patricia. 1997. Birth order. Reconciling conflict effects. American Psychologist. 52(*7*):685-699.

Zajonc, Robert. 2001. The family dynamics of intellectual development. American Psychologist. 56(6/7):490-496.