Why Do Mothers Favor Girls and Fathers, Boys?

A Hypothesis and a Test of Investment Disparity

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Growing evidence suggests mothers invest more in girls than boys and fathers more in boys than girls. We develop a hypothesis that predicts preference for girls by the parent facing more resource constraints and preference for boys by the parent facing less constraint. We test the hypothesis with panel data from the Tsimane', a foraging-farming society in the Bolivian Amazon. Tsimane' mothers face more resource constraints than fathers. As predicted, mother's wealth protected girl's BMI, but father's wealth had weak effects on boy's BMI. Numerous tests yielded robust results, including those that controlled for fixed effects of child and household.

KEY WORDS: Bolivia; Parental investment; Sex bias; Trivers-Willard; Tsimane'

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In recent years economists and researchers using evolutionary theory have converged in their approaches to the study of parental investment in daughters and sons. Both groups stress the role of resource constraint in skewing parental investments either to maximize the socioeconomic well-being of the household (Behrman 1997; Dasgupta 1993) or to enhance inclusive fitness (Borgerhoff Mulder 1998; Cronk 2000; Koziel and Ulijaszek 2001; Mace 1996; Trivers and Willard 1973). The two approaches complement each other. Economic theory suggests that constraint on resources produces unequal allocation of goods and services within the household (Mirrlees 1976; Stiglitz 1976) but makes no prediction about the sex of the child of choice. The Trivers-Willard hypothesis from evolutionary biology predicts that under some conditions, constraint on resources will induce both parents to skew investments to daughters and the lifting of constraints will induce both parents to skew investments to sons (Trivers and Willard 1973). Constraint on resources refers to limited access to credit, or limited opportunities to earn income or to accumulate financial, physical, or human capital. The easing of resource constraints refers to increased opportunities to gain access to credit, employment, or assets.

When combined, the two approaches help answer a puzzle that has received scant attention in studies of household allocation: Why would parents in the same household *differ* in their investments in daughters and sons? Growing evidence suggests that mothers skew investments to daughters and fathers to sons. For instance, the study by Thomas (1994) in Brazil, the United States, and Ghana found that mother's schooling had a greater positive impact on a daughter's standardized *z*-score of height for age than on a son's *z*-score of height for age, whereas father's schooling had a greater positive impact on a son's than on a daughter's *z*-score of height for age. Psychologists find that mothers and fathers in the United States interact with and treat daughters and sons in different ways (Keller 2002; Weinberg, Tronick and Cohn 1999). In the United States, white mothers who headed the household after their marriages broke up paid more attention to daughters than to sons; attention to girls declined when fathers were present (Mott 1994). Lundberg and Rose (2002) found that the birth of a son (but not of a daughter) increased the labor supply and the hourly wage of fathers but not of mothers.

The question we pose, "Why would parents in the same household *differ* in their investments in daughters and sons?" goes beyond the standard question of why both parents—as a couple—might favor children of one sex over the other, or why they might favor children of a certain birth order (Draper and Hames 2000; Ejrnaes and Portner 2004; Salmon 2003). Growing research in economics and in anthropology suggests that wives and husbands do not always pool resources. Spouses keep assets separate and differ in patterns of consumption, investments, and leisure (Godoy 2002). Husbands and wives pool resources if they consume from a common pot, put all their income in a common account, make joint investment and production decisions, and allow each other full access to their knowledge and other resources. At the other extreme, husbands and wives might keep assets and income separate, work different plots, have full control over the resources they produce, and make

investment decisions on their own without consulting their partner. The empirical challenge lies in identifying resources controlled separately by wives and husbands, documenting resource constraints and lack of pooling, estimating whether parents invest resources unequally between girls and boys, and then assessing the effects of differential investments on child well-being.

We draw on insights from economics and evolutionary theory to develop and test a hypothesis about why parents differ in their investments toward daughters and sons. To test the hypothesis we use repeated observations collected from the same people during five consecutive quarters from Tsimane' Amerindians, a low-income foraging-farming society in the Bolivian Amazon.

THEORIES OF DIFFERENTIAL PARENTAL INVESTMENT IN DAUGHTERS AND SONS

Evolutionary Biology

In 1973 Trivers and Willard argued that among mammals, systematic departure from even sex ratios enhanced parental fitness. They hypothesized that among humans, the socioeconomic status of the parents would correlate positively with investments in boys. To maximize the eventual reproductive success of their offspring, parents in better reproductive and socioeconomic conditions would bias investments in favor of boys, and parents in poorer conditions would bias investments in favor of girls. Parents display biases by manipulating the sex ratio, or by investing in the offspring of choice. Trivers and Willard suggested that among humans socioeconomic status might serve as a proxy for parental condition (Koziel and Ulijaszek 2001).

The Trivers-Willard hypothesis rests on four assumptions (Gaulin and Robbins 1991; Koziel and Ulijaszek 2001). First, males must display greater variance in reproductive success than females. Second, parents must be able to consciously or unconsciously assess the potential reproductive success of themselves and their children. Parents transmit their condition to their children, so parents in good condition produce offspring in good condition, and parents in poor condition produce offspring in poor condition. The condition of the child as an adult mirrors the condition of the parents when the parents invested in their offspring. It is still unclear what cues from the child (if any) parents use to assess the reproductive success of the child, or whether the only cues come from the parents' own condition. Having assessed their own and their children's potential reproductive success, parents allocate investments between daughters and sons. Third, social stratification and people's position in the social hierarchy are stable and heritable so parents pass their position and condition to their children. Fourth, parents pool resources and share investment preferences about their children. Parents invest based on the reproductive prospects of the child; objective prospects should be the same for mothers and fathers—hence the convergence in preferences. Because parents pool resources and

share investment preferences, researchers studying human populations often use the sum of the resources of the mother and the father when analyzing differences in parental investment between girls and boys.

Researchers in many disciplines have tested the Trivers-Willard hypothesis. Support for the hypothesis has been strong among non-human mammals and mixed among humans. Cameron (2004) found in a meta-analysis of 44 studies testing the Trivers-Willard hypothesis among non-human mammals that 74% of the studies supported the idea that mothers in good condition around conception (but not around birth or gestation) favored male offspring as shown in sex ratios at implantation. In a meta-analysis of studies among non-human primates, Brown and Silk (2002) found support for the Trivers-Willard hypothesis. High-status females had more male than female offspring relative to low-status females, but the difference fell with larger samples. Other studies among non-human primates contradict Trivers-Willard (Hrdy 1999; Brown and Silk 2002). For example, Gaulin and Robbins (1991) found that high-status mothers skewed investments toward females rather than males.

Historians and researchers in the behavioral sciences have tested the Trivers-Willard hypothesis among humans. Historical demography suggests that European sex ratios, patterns of childhood mortality, and parental bequests follow the predictions of Trivers-Willard (Gaulin and Robbins 1991; Voland 1984). Several researchers have reviewed studies in the behavioral sciences that test the Trivers-Willard hypothesis among contemporary populations of industrial and preindustrial nations (Borgerhoff Mulder 1998; Cronk 2000; Koziel and Ulijaszek 2001). Researchers typically find support for the Trivers-Willard hypothesis, but they also find instances that do not support the hypothesis.

Many of the early tests relied on descriptive and bivariate analysis (Betzig and Turke 1986; Cronk 1989, 1991), making it difficult to tell whether results would hold after conditioning for omitted variables that affect parental investment and socioeconomic status. More recently, researchers have controlled for the role of third variables and included interaction terms between the sex of the child and the investment resource. These more recent studies still support Trivers-Willard, though not for all types of investment resources (Borgerhoff Mulder 1998) or for both parents (Koziel and Ulijaszek 2001).

One last field of research that has produced support for Trivers-Willard comes from the biomedical and health sciences. Negative environmental and health shocks, such as exposure to floods, earthquakes, or smog near the time of conception, skews sex ratios in favor of girls (Hansen, Moller, and Olsen 1999). Adverse shocks to income lower the socioeconomic status or reproductive condition of parents, inducing them to shift investments in favor of daughters, as predicted by Trivers-Willard.

Economics

Economists trace unequal allocation of goods and services in the household to market constraints. The work of Mirrlees (1976) and Stiglitz (1976) going back to

the mid 1970s suggests that poor households do not allocate resources equally between girls and boys because a household can maximize its total work capacity better through unequal allocations of resources (Ray 1998). Many case studies in economics have confirmed the hypothesis of unequal allocation of resources in the household when households face resource constraints (Deaton 1997). When parents have limited resources, and when they cannot borrow to make equal investments among all their children, they have to make hard choices regarding which children to invest in, and children have to compete with each other for the scarce resources of their parents (Garg and Morduch 1998).

Economists have focused on explaining unequal allocation of resources between girls and boys rather than explaining why parents differ in their investments in girls and boys. As far as we know, only Thomas (1994) offers such an explanation. In his comparative study mentioned earlier, Thomas borrows from sociology and social psychology to explain the finding of "like father, like son; like mother, like daughter." He says children learn more from the parent of the same sex because that parent provides the child with an adult role model. Mothers might invest more in daughters and fathers might invest more in sons because daughters would be more likely to help mothers with female tasks and sons would be more likely to help fathers with male tasks. It follows that if a mother has favorable attributes, she would more easily transmit them to her daughter than to her son because of the sexual division of labor and because mothers would be likely to spend more time with daughters than sons. One would then see sex links across generations. For example, an educated mother knowledgeable about good health would more likely transmit better health to her daughter than to her son because the daughter identifies and spends more time with the mother and, in so doing, learns more about health practices.

Thomas's explanation accounts for why mothers favor daughters and fathers, sons, but it does not account for other types of differences between parents investing in girls and boys. For instance, in some societies mothers invest more heavily in sons and fathers invest more heavily in daughters (Cronk 1991; Haddad and Hoddinott 1994; McDowell 1991), and in some societies only the investment of the father matters in shaping child outcomes (Koziel and Ulijaszek 2001). A unified theory of why parents invest differently in daughters and sons should explain all possible forms of mother-offspring, father-offspring preference, not just mother-daughter, father-son preference.

In several publications, Berhman (1997, 1998) summarizes the difficulties of inferring discrimination between girls and boys within households from observational studies. The chief difficulties have to do with estimation biases from unobserved, unmeasured fixed heterogeneity in endowments and preferences of parents and children, with the role of unmeasured omitted variables that vary over time, with classical measurement errors of explanatory variables, and with possible reverse causality.

One cannot rely on inequality in outcomes between girls and boys to infer un-

equal allocation within the household because differences in outcomes might reflect the role of observed or unobserved third variables (Cronk 1991). For instance, disparity in juvenile sex ratios in favor of girls could reflect greater vulnerability of boys during childhood. Nor can one rely on unequal investment of resources by parents in girls and boys because unequal investment could reflect parental concerns with equity over efficiency. Unequal allocation of investment could reflect parental desires to level the playing field by investing more in children with weaker initial endowments (Pitt, Rosenzweig, and Hassan 1990) or in children likely to face more severe constrains on resources as adults. The absence of unequal allocation of resources or the absence of significant disparities in outcomes could also reflect attenuation bias.

Providing convincing evidence of discrimination requires attention to other topics besides the ones just noted. Discrimination requires a life-cycle perspective (Sieff 1990). Parents might under-invest in children of one sex during one stage in the child's life cycle but compensate by investing more in the same child during another stage. Further, discrimination requires attention to the resource being invested. Parents might skew some types of investments to children of one sex and other types of investments to children of the other sex (Borgerhoff Mulder 1998; Quisumbing 1994).

At least three conclusions emerge from the literature just reviewed. First, researchers agree that resource scarcity affects parental investment in daughters and sons, but they disagree on what happens to parental investments with the easing of resource constraints. The Trivers-Willard hypothesis predicts that relaxing resource constraints induces a change in parental investment in favor of boys. Economic theory yields unclear predictions (Garg and Morduch 1998). Behrman (1998) says that easing resource constraints causes a shift from concerns with efficiency to concerns with equity. Empirical support for Behrman's observation comes from case studies which suggest that households constrained by resources deflect investments away from children at high risk (Bereczkei 2001; Bereczkei, Hofer, and Ivan 2000) but increase investment in those children with the easing of the constraints. Second, in estimating the differential effect of parental investments in girls and boys, researchers must control for many possible biases before inferring causality. Last, researchers have generally assumed that resource constraints affect the entire household and both parents in the same way; thus, resource constraints make parents converge in their investment preferences to their children. Faced with the same resource constraints affecting the entire household, both parents favor either girls or boys. But what happens to parental investment in children when market constraints affect the mother and the father in different ways, and when parents do not pool resources or information?

THE HYPOTHESIS

We hypothesize that if parents do not pool an investment resource and if they face different constraints on the resource, then the parent facing greater constraints will invest more of the resource in daughters than in sons, and the parent facing lighter constraints on the resource will skew investments of the resource in favor of sons over daughters. We borrow the *spirit* of the Trivers-Willard hypothesis—the idea that the parent facing greater resource constraint will deflect investments to girls—and push the standard economic analysis by bringing it down to the constraints faced by each parent. We relax the assumption that resource constraints apply to both parents in the same way, or that spouses share preferences when investing in their children.

The Tsimane' provide an apt case to test the hypothesis for two reasons. First, they have low income and face resource constraints, so one should expect unequal allocation of resources between girls and boys based on standard economic thinking. Mean annual personal income reaches only $342, a third of the national average in Bolivia ($980), one of the poorest nations in Latin America (Godoy et al. 2002). Only 16% of people over the age of 16 reported having access to credit. Second, mothers face more resource constraints than fathers. Mothers earned 13% of the cash income of the father, obtained in credit 12% of the amount of credit obtained by the father, had physical assets worth 32% of the value of assets held by the father, had fewer modern physical assets than the father, and had only 1.1 year of schooling, compared with 2.4 years of schooling for the father. Since mothers face more severe resource constraints than fathers, we expect them to skew investments to daughters and fathers to sons.

Tsimane' pool food consumption in the household, often literally eating from the same pot, but they have private ownership of physical assets. Mothers and fathers own separate assets and can sell or swap them without consulting their spouse. People know who owns each asset and which assets are owned by the entire household. People begin to accumulate assets early in life. Parents give small domesticated animals as gifts to children as young as 5–6 years of age. The child receiving the gift owns the animal and can dispose of the animal or its products (e.g., eggs) without consulting the parent. Although assets have clear owners in the household, people in the household borrow each other's assets. Unfortunately, we lack data to estimate sharing inside the household.

THE PEOPLE

The latest Bolivian census puts the Tsimane' population at ca. 8,000 people (Instituto Nacional de EstadÌstica 2003). The Tsimane' are a typical native Amazonian population. People live in villages of ca. 18 households along riverbanks and logging roads. Subsistence centers on hunting, fishing, and swidden farming. Tsimane' practice cross-cousin marriage, which creates a wide web of relatives linked by mar-

riage and blood. Residence is matrilocal shortly after marriage, followed by neolocal residence. Tsimane' live in nuclear households and mostly practice monogamy. In a survey done during 1996 among 208 households, we found that only 5.31% of households practiced polygyny, and that only 5.72% of household heads lived with their parents. Tsimane' marry within their ethnic group; few marry people from neighboring Amerindian groups, and almost no one marries a non-Amerindian.

Tsimane' remained relatively isolated from outsiders until the 1970s. During the 1970s the opening of roads brought loggers, ranchers, oil firms, and highland colonist farmers into or next to the territory of the Tsimane'. Contact with outsiders centers on the sale of rice and forest goods and on work as unskilled laborers. The most important market good Tsimane' acquire is food (e.g., canned meat, oil) followed by clothing.

To assess whether girls and boys differ in indicators of well-being, in Table 1 we compare anthropometric indices of short- and long-run nutritional status, perceived health, and modern human capital of girls and boys. A comparison of mean differences between girls and boys suggests no strong evidence of unequal outcomes in favor of children of one sex. Girls do better than boys in muscularity and protein reserve as measured by mid-arm muscle area (ZAM). Girls do better than boys in weight for age (ZWT) and height for age (ZHT), and are less likely to be stunted (ZHT ≤ -2). Boys have slightly higher BMI, less perceived illnesses, and slightly more schooling. We found no statistically significant differences at the 10% level in sum of skinfolds, wasting, incidence of low weight, medical expenditures, days confined to bed from illness, or in the age when the child first enrolled in school. Elsewhere we show that girls and boys do not differ in levels of C-reactive protein, a non-specific biomarker of infection, or in rates of parasitic infections (McDade et al. 2005; Tanner et al. 2004).

ESTIMATION STRATEGY

Researchers have drawn on two approaches when using multivariate analysis to test investment disparities within households between girls and boys. Economists generally interact a variable for the child's sex with a parental *resource* (e.g., income) and use an indicator of child well-being (e.g., health) as a dependent variable (Hoddinott and Haddad 1995; Thomas 1994). Evolutionary biologists use the same explanatory variables, but as dependent variables use instead the actual investment (e.g., length of breast-feeding) in the child by the parent. The first approach tests for inequality in well-being between girls and boys as a function of an investment resource; the second approach tests for inequality in parental investments between girls and boys, also as a function of an investment resource.

We use the first approach because we do not have data on parental investments, except for medical expenditures. The variable for medical expenditure was censored at zero (72% of observations had values of zero) and were likely measured with random error owing to faulty recall. Instead, as a dependent variable we opted

Table 1. Comparison of Well-Being between Tsimane' Girls and Boys (2–13 years of age)

	Girls			Boys			Difference	
Outcome	*N*	Mean	s.d.	*N*	Mean	s.d.		
NUTRITIONAL STATUS: *t*-test								
ZAM	1229	–.264	0.821	1440	–.530	0.742	8.78	–0.01
ZHT	1247	–1.540	1.142	1458	–1.699	1.124	3.63	–0.01
ZSF	1224	–.530	0.529	1436	–.501	0.534	1.42	–0.15
ZWT	1254	–.736	0.743	1452	–.784	0.715	1.71	–0.08
BMI	1246	16.736	1.824	1451	16.939	1.421	3.23	–0.01
NUTRITIONAL STRESS: χ^2 (%)								
Stunted	1361	0.32	0.466	1575	0.364	0.481	6.28	–0.01
Wasted	1361	0.004	0.066	1575	0.004	0.066	0	–0.98
Low weight	1361	0.021	0.144	1575	0.027	0.163	1.09	–0.29
PERCEIVED HEALTH: *t*-test								
Number of ailments	1243	0.658	0.651	1449	0.568	0.621	3.63	–0.01
Bed days	1243	0.815	1.985	1449	0.844	1.888	0.38	–0.7
Spending	712	2.716	11.248	732	2.964	8.802	0.46	–0.64
SCHOOLING: *t*-test								
Age start	146	6.075	1.226	188	6.042	1.098	0.25	–0.79
Schooling	136	0.875	0.992	163	1.073	0.933	1.78	–0.07

Notes: ZAM = age and sex-standardized mid-arm muscle area. ZHT = height for age. ZSF = age- and sex-standardized sum of triceps and subscapular skinfolds. ZWT = weight for age. BMI = body-mass index (kg/m^2). ZAM, ZHT, ZSF, and ZWT follow Frisancho 1990. Stunted = ZHT ≤ –2, low weight = ZWT ≤ –2, wasted = *z*-scores of weight for height ≤ –2 using National Center for Health Statistics standards. Number of ailments = total ailments reported for the two weeks before interview. Bed days = number of days child confined to bed from illness during previous two weeks. Spending = total value in bolivianos of medical expenditures (including time costs) to treat illness in last two weeks for people reporting illness. Age start = age at which child first enrolled in school (first quarter). Schooling = maximum school grade of children 6–13 years of age (fifth quarter). Under column "Difference" first number is *t* or χ^2 value and second is the $p > |t|$ in *t*-test of comparison of means or the probability of exceeding the χ^2 value.

to use BMI, a reliable general measure of short-run nutritional status, even for children as young as 2 years of age (Dietz and Bellizzi 1999).

BMI has several advantages over other outcomes. First, unlike the actual parental investment in the child, BMI contains no zeros and has low random measurement error (see below). Second, BMI reflects short-run nutritional status and, among older children, reflects potential reproductive success. Body fatness in girls correlates with age at menarche, which allows girls to become reproductively mature at an earlier age. Third, in a short panel with only five quarters of observations, one can spot changes in BMI because BMI responds to short-run changes in diet, health, and physical activity. As a parental investment resource we used the value of modern physical assets owned, separately, by the mother and the father.

We estimate the parameters for the following expression:

$$H_{ithv} = \alpha + \beta_1 X_{1ihtv} + \beta_2 X_{2ihv} + \beta_3 X_{3htv} + \beta_4 X_{4htv} + \sum_{X2}\sum_{X3} \beta_{x2x3} (X_{2ihv} * X_{3htv}) + \sum_{X2}\sum_{X4} \beta_{x2x4} (X_{2ihv} * X_{4htv}) + \beta_5 X_{5ihtv} + \beta_6 X_{6ihtv} + \varepsilon_{ihtv} \quad [1]$$

H_{ithv} is the BMI of child *i* of household *h*, village *v*, at time *t*. X_{1ihtv} is the child's age. X_{2ihv} is a binary dummy variable for the child's sex (boy = 1; girl = 0). X_{3htv} and X_{4htv} are the investment resources or the value of modern physical assets of mothers (X_{3htv}) and fathers (X_{4htv}). X_{5ihtv} is a vector of 12 dummy variables for villages ($n = 13 - 1 = 12$). X_{6ihtv} includes a vector of control variables, such as parental schooling and age, household size, and dummy variables for quarters, which we use to control for the effects of seasons and inflation. E_{ihtv} is a random disturbance term.

We measured the following 13 modern physical assets: bicycles, rifles, shotguns, cooking pots, fishing nets, machetes, axes, mosquito nets, radios, watches, rice millers, metal knives, and fishhooks. We focused on modern assets for three reasons. First, unlike consumption, which is pooled, modern assets have individual owners. Second, modern assets have less random measurement error and more variance than other investment resources (e.g., income). Modern assets have a village market price so one can value them with ease. In contrast, traditional assets (e.g., bows, canoes) lack a well-developed market, making it hard to price them with accuracy. Income is hard to measure with accuracy in rural areas of developing nations, both because of faulty recall and because much of it comes from people's consumption of their own production. Further, 94% of mothers had positive values for modern wealth, whereas 40% of mothers had no monetary earnings, 71% had no credit, and 55% had no schooling. The use of income, credit, or schooling as an investment resource would have produced weaker results because the variables lacked as much variance as modern physical assets. Last, modern physical assets relate in obvious ways to health (e.g., mosquito nets) or nutritional status (e.g., fishhooks).

We care mostly about the coefficients of the two interaction terms, β_{X2X3} and β_{X2X4}. The coefficients capture the difference in the investment resource of mothers (β_{X2X3}) and fathers (β_{X2X4}) toward boys *relative* to girls. The coefficient β_{X2X3}

tells us whether a unit of modern wealth owned by the mother has the same impact on a girl's BMI as it does on a boy's BMI; the coefficient β_{X2X4} tells the same story for the father, and a test of the equality of the coefficients of the two interaction terms, $\beta_{X2X3} = \beta_{X2X4}$, tells us whether a unit of modern wealth in the hands of a mother and a father produces similar effects on the BMI of a girl as it does on the BMI of a boy. We next discuss how we control for the biases discussed earlier when estimating parameters for expression 1.

To control for unobserved fixed heterogeneity of child endowments or household attributes we use fixed-effect models of children and households. We can do so because we have repeated observations from the same people and households. To control for the bargaining power of the mother we add various proxies for bargaining power. To control for village fixed effects we add a full set of village dummies in all regressions.

Although the *level* of own parental modern assets and the *level* of a child's BMI may affect each other reciprocally (e.g., sick children may draw down the level of wealth of a parent), the *differential* effect or *interaction* of a parental resource with the sex of the child (β_{X2X3} and β_{X2X4} in expression 1) should be free of biases from reverse causality (Thomas 1994).

Two sources of attenuation bias deserve discussion. The variable for modern wealth might contain random measurement error if some of the assets owned by mothers were, in fact, bought by the father. We do not have information on who bought the asset or on how often spouses shared the asset; we only have information on who owned the asset at the time of the survey. The omission makes it difficult to reach firm conclusions about how assets in the hands of mothers and fathers affect child outcomes. For instance, suppose the mother and father agree to invest more in a daughter than in a son; the father might acquire modern assets for the mother, who would then use the assets to favor the daughter. Then it would appear as though only maternal assets affected child outcomes, when, in fact, the effect of modern assets on child outcomes would reflect a joint investment decision by both parents.

Last, we do not have kinship data to link parents with their offspring in a household. In each household, we surveyed both the female and the male head of the household (and other adults), and we took anthropometric measures of all children in the household. We assumed that the male household head was the biological father of the children in the household. This would be incorrect in households with stepfathers. Random measurement errors in paternity work in our favor; if we find a significant result we can infer that the true effect would be stronger. In the balance of the article we use the terms *mother* and *father* to mean female and male head of a household.

DATA AND VARIABLES

For the analysis we draw on data from five consecutive quarterly surveys done between August 2002 and November 2003. We did the surveys among 907 children

(436 girls; 471 boys) and their parents in 246 households and 13 villages along the river Maniqui, department of Beni. Children's age ranged from 2 to 13 years. We selected villages that varied in distance from the market town of San Borja (population ca. 18,000) to capture cross-sectional variance in participation in the market economy. We surveyed all people in each village. Table 2 contains definition and summary statistics of the variables used in the regressions.

Dependent Variable: BMI

To estimate BMI we followed the protocol of Lohman et al. (1988) and measured people in light clothing without shoes or hats. We recorded physical stature (standing height) to the nearest millimeter using a portable stadiometer or a plastic tape measure and body weight to the nearest 0.20 kg using a standing scale.

Main Explanatory Variable: Modern Wealth

We asked household heads and all people over the age of 16 to report how many of the 13 modern physical assets listed earlier they owned. In each village we collected the community price for each good. We multiplied the community price of the good times the quantity of the good owned by the person to arrive at the value of the stock of that good. We added the value of different types of assets to arrive at a total value of modern wealth for the person. We transformed wealth and BMI into logarithms to facilitate the interpretation of results. We did separate *t*-tests for each of the 13 assets to assess who owned more assets and found that fathers owned more of all assets (except for large cooking pots) than mothers; in only one of the 13 tests were results statistically insignificant at the 10% level.

MAIN RESULTS

We used the Breusch-Pagan Lagrangian multiplier test for random effects and rejected the null hypothesis at the 99% confidence level, so we use random-effect models, but we also use fixed-effect models for households and children to control for some of the biases discussed earlier.

Column A of Table 3 presents the main results. Mother's modern wealth had the expected correlation with the BMI of girls and boys. A doubling of mother's modern wealth correlated with ~0.10% *net* quarterly *increase* in girl's BMI and with ~0.20% *net* quarterly *decrease* in boy's BMI ($p < 0.06$) (rows 5 and 6). Father's wealth did not correlate significantly with the BMI of children (rows 7 and 8). In row 9 we show the results of a test of the equality of the coefficient for the two interaction terms, β_{X2X3} and β_{X2X4} (mother's wealth * boy = father's wealth * boy), from expression 1. The results suggest that wealth in the hands of mothers and fathers correlated differently with the child's BMI, depending on the child's sex ($F = 7.28$, $p > F = 0.02$). The results of row 3 suggest that a doubling of mother's

Table 2. Definition and Summary Statistics of Variables Used in Regressions

Variable	Description	*N*	Mean	s.d.
DEPENDENT VARIABLE				
BMI	kg/m^2 for children ages 2–13; in regression, entered in logarithms	4677	19.62	3.85
EXPLANATORY VARIABLES				
Mothers				
Education	Maximum schooling attained by mother at start of first quarter	246	1.10	1.49
Age	Age of mother in years in first quarter	246	35.65	15.01
Wealth	Quarterly value (in bolivianos) of 13 modern commercial physical assets; see text for list of assets. In regressions, entered in logarithms (US $1 = 7.45 bolivianos)	1179	228	320
Fathers				
Education	Maximum schooling attained by father at start of first quarter	246	2.2	2.87
Age	Age of father in years in first quarter	246	37.09	14.55
Wealth	See wealth under "mothers" above	1177	1159	949
Household Level				
Household size	Household size during each quarter measured with a head count	1218	5.96	2.73
Children (during first quarter)				
Age	Age of child in years	644	6.81	3.07
Boy	Sex of child (1 = boy; 0 = girl)	644	0.53	0.49

wealth correlated with a *lower* quarterly growth rate of BMI of ~0.3% for boys *relative* to girls ($p < 0.02$).

The main results lend partial support to our hypothesis that modern wealth in the hands of the parent facing greater resource constraints (the mother) correlates with greater improvement in BMI of girls relative to boys. We had hypothesized that the

Table 3. Regression Results: Effects of Mother's and Father's Wealth in Modern Assets on Logarithm of Quarterly Body-Mass Index for Children 2–13 Years of Age

	Robustness: Change introduced to equation 1				
Variable	Main results [A]	Child fixed effect [B]	Household fixed effect [C]	BMI baseline [D]	Child illness [E]
DIRECT EFFECT					
1. Mother's wealth	0.001	.001	.001	.002*	.001
	(.001)	(.001)	(.001)	(.001)	(.001)
2. Father's wealth	–0.003	–.006**	–.00526**	–.00448**	–.002
	(.002)	(.002)	(.002)	(.002)	(.002)
INTERACTION EFFECT					
3. Mother's wealth* boy	–0.003**	–.004**	–.004**	–.004***	–.003**
	(.001)	(.001)	(.001)	(.001)	(.001)
4. Father's wealth * boy	0.005	.007**	.005348*	.004112	.004
	(.003)	(.003)	(.003)	(.002)	(.003)
TOTAL EFFECT (direct + interaction)					
Mother					
5. Boy	–0.002*	–.003**	–.003*	–.002**	–.002*
6. Girl	0.001*	.001**	.001*	.002**	.001*
Father					
7. Boy	0.002	.001*	0.00008	.0003*	0.002
8. Girl	–0.003	–.006*	–.005	–.004*	–.002
TESTS OF JOINT SIGNIFICANCE					
9. [3] = [4]	7.28 (0.02)	4.90 (.007)	7.47 (.023)	9.99 (.006)	5.30 (.070)
10. [1] + [3]	5.44 (0.06)	3.04 (.048)	5.27 (.071)	8.30 (.015)	4.46 (.107)
11. [2] + [4]	2.88 (0.23)	2.82 (.060)	4.15 (.125)	5.01 (.081)	1.74 (.418)
R^2 (overall)	0.18	0.008	0.394	0.577	0.180
N	2589	2589	2589	2468	2421

Notes: Variables not shown = age and sex of child, mother's and father's age and schooling, household size/quarter, dummies for quarters and villages, and constant. Row 9 is F test and $p > F$ for equality of the two interaction variables; rows 10 and 11 are tests of joint significance of direct and interaction effects. Standard error in parenthesis. Column C = A but includes dummies for households. D includes child's BMI in first quarter. E controls for number of bedridden days of child for 14 days before the interview. A, D, and E are random-effect regressions.
*, **, and *** significant at ≤10%, 5%, and 1%

parent facing less severe resource constraints (the father) would use resources to favor boys, but our results did not support this expectation. As suggested, fathers may transfer or buy assets for mothers, who might use them to invest in the child of choice.

ROBUSTNESS AND EXTENSIONS

In columns B–E we show the results of analysis to ensure the robustness of the main results. Column B shows the results of a fixed-effect model for the child. Unlike the main results, the results of the fixed-effect estimation for the child fully confirm our hypothesis. Doubling mother's modern wealth correlated with a *positive* quarterly growth rate of ~0.1% in girl's BMI and with a *negative* quarterly growth rate of ~0.3% in boy's BMI (rows 5 and 6). Doubling father's modern wealth correlated with a 0.1% positive quarterly growth rate in boy's BMI and with a negative quarterly growth rate of ~0.6% in girl's BMI (rows 7 and 8).

In column C we control for the fixed effect of the household. Results resemble the main results shown in column A and provide only partial confirmation for the hypothesis. Mother's modern wealth enhanced the BMI of girls more than the BMI of boys, and father's modern wealth produced no significant effect on the BMI of either daughters or sons. Doubling the value of mother's modern assets correlated with a positive quarterly growth rate in girl's BMI of ~0.1% and with a negative quarterly growth rate in boy's BMI of ~0.3% (rows 5 and 6).

In columns D and E we control for the child's BMI at baseline and for the number of bedridden days of the child during the two weeks before the day of the interview. The intuitive thinking behind D is that parents might use their child's BMI as a cue to assess their children's reproductive prospect and, based on the cue, decide how to invest (Bereczkei 2001). The results of column D provide strong confirmation for our hypothesis. Doubling the value of mother's modern wealth correlated with a ~0.2% increase in the quarterly growth rate of BMI of girls and with a ~0.2% decrease in the quarterly growth rate of BMI of boys (rows 5 and 6). Doubling the value of father's modern wealth correlated with a ~0.03% increase in the quarterly growth rate of BMI of boys and with a ~0.4% decrease in the quarterly growth rate of BMI of girls (rows 7 and 8). Last, controlling for child illness as perceived by the principal caretaker (column E) produced parameter estimates similar to the ones in the main regression.

We did other types of analysis not shown in Table 3. We tested for interaction with distance and income levels under the assumption that in more remote communities or among poorer households facing more severe resource constraints one might detect stronger effects. To explore the topic, we split the sample into the top and bottom 25% of the income distribution, and we repeated the analysis separating the sample between the 25% most remote and the 25% most accessible households (i.e., households closest to roads and market towns). In no case did we find a statistically significant result, probably because of the loss of statistical power from us-

ing a smaller sample size when restricting the analysis to only a quarter of the sample.

Parents' modern wealth might affect child well-being only if parents have bargaining power in the household. To explore the topic, we created two variables to proxy for the bargaining power of the mother. We created a dummy variable that assigned a value of 1 if the mother resided in her village of birth and the father married into the mother's village; the excluded category (0 value) was all other possible types of postmarital residence. The intuitive reasoning is that a woman's bargaining power would increase if she resided in the village where she grew up because she would have a larger network of kin for support, whereas the father would have a weaker network of support. This intuition is only partially correct because cross-cousin marriage and fluid postmarital residence create a diffuse kin network cutting across villages. To address this concern, we created a second proxy for bargaining power by taking the absolute value of the difference between the modern wealth of the mother and that of the father. A larger gap would signal weaker bargaining power. We reestimated the model of column A, adding the two variables one at a time, and found results similar to those of the base model.

Last, we carried out the conventional test of intra-household discrimination by pooling the modern wealth of the wife and the husband. In Table 3 we kept the modern wealth of the wife and husband separate because we hypothesized that when parents do not pool resources in full, and when each spouse faces different resource constraints, we should see divergence between parents' investment in girls and boys. We reestimated the parameters of column A in Table 3 by dropping the wealth of each parent and including a variable that combined the wealth of the mother and the father. We interacted total spousal modern wealth with the sex of the child, and included as explanatory variables total modern household wealth and all the other explanatory variables of column A. We found no evidence for unequal effects: doubling the level of total spousal modern wealth correlated with a decrease of ~0.38% per quarter in boys' BMI relative to that of girls ($t = 0.84$; $p < 0.40$). The results highlight the importance of treating the resources of spouses separately when testing for girl-boy discrimination if spouses face different resource constraints. If parents had faced the same constraints and had the same investment preferences, and if they pooled their resources, then treating their resources separately or combined should have produced roughly similar results. Combining the modern wealth of mothers and fathers produced weaker effects on child BMI because the effect of wealth on the BMI of girls and boys differs depending on which parent is controlling the wealth.

DISCUSSION AND CONCLUSIONS

Despite possible measurement errors in BMI and modern wealth, lack of precision in linking children to genetic parents, and lack of information on who bought the physical assets, we find that modern physical assets in the hands of mothers corre-

lated with larger improvements in the BMI of girls *relative* to boys; results held up under a wide range of tests. We discuss three topics by way of conclusion: (*a*) the absence of significant effects for fathers, (*b*) possible paths by which modern wealth might shape child BMI, and (*c*) other explanations of why mother's wealth might benefit girls more than boys.

One possible reason for the weak effect of father's modern wealth on children's BMI might have to do with separation and remarriage. If fathers are more likely to move away after separation, or if they have more mating opportunities, they might face fewer incentives to invest in their children. In our data, the link between the female household head and the children in the household is most likely the link between a mother and her children. With dissolution, there is a higher likelihood that the link between the male household head and the children in the household might be those of a stepfather and a stepchild. We doubt the error is serious because ethnographic observations suggest that separation is rare, but we cannot rule out the possibility. Another possible reason is that among Tsimane', modern wealth might be a stronger determinant of nutritional status and reproductive performance for females. Father's wealth might matter, but only if fathers reach a threshold of wealth, which they have yet to attain. Last, if the father buys modern assets for the mother, the effect of modern assets of the father on the BMI of children would be indirect and weaker.

At least three paths might explain why modern assets correlate with higher BMI. First, modern assets, such as machetes, fishing nets, fishhooks, or axes, improve farming and foraging productivity, so access to them should enhance a parent's capacity to obtain more food and thus improve the nutritional status of children. Other assets (e.g., mosquito nets) protect health and, through health, nutritional status. A mother with modern assets might be able to catch more fish or obtain more food. Since women normally prepare the food, mothers might give more or more nutritious foods to some children without the interference of the father. Mothers might give fishhooks to their daughters, who would then be able to fish more and eat the fish they catch. The problem with this line of thinking is that much food consumption takes place at home, with people often helping themselves from a common pot. Second, parents with modern assets might be able to better protect their children against parasitic infections by, for instance, buying them shoes, or by having pots to boil water, or by spending more on health care. Last, parents with modern wealth might be able to reduce the workload or energy expenditure of children, which would contribute to higher BMI. We have no data on child time allocation to test this path, but it remains a theoretical possibility.

We end by discussing other possible explanations for why mother's wealth might have a greater protective effect on the BMI of daughters than on sons. Recall from Table 1 and the earlier discussion that Tsimane' children do not display obvious disparities in indicators of well-being. In fact, Table 1 even hints that girls do better than boys in many indicators of nutritional status. The market sends cues that boys, as adults, will do better in the market economy. If parents responded to efficiency,

the cues of the market would induce them to invest in boys since boys, as adults, would earn higher cash incomes. In an earlier study of only two villages and 60 households in which data were collected for five consecutive quarters (1999–2000), we found that even in the value of goods extracted from farms, rivers, and forests, men contributed ~50% more to the household than women. One possible interpretation of the protective effect of maternal modern wealth on girls might relate to attempts by mothers to equalize outcomes in favor of the sex most likely to face greater resource constraints later in life. If true, this would imply that maternal concerns with equity overshadow concerns with efficiency. The results parallel Leonard's (1991) finding among Aymara Amerindians in the nearby Peruvian Andes. Last, like the Gypsies described by Bereczkei and Dunbar (2002) or the Mukogodo described by Cronk (2000), the Tsimane' occupy the lowest rung of the regional social hierarchy. Mothers might invest in daughters in hopes that they will marry white men or at least out of Tsimane' society. The problem with this interpretation is that most Tsimane' marry other Tsimane'.

In sum, the results highlight the promise of combining insights from evolutionary biology and economics to gain a finer-grained understanding of investment decisions inside the household and the usefulness of panel data to study the topic. Evolutionary biology helps to explain parental preferences, economics provides the analytical tools to obtain estimates, and panel data allows one to control for biases difficult to control in a cross-sectional study. We find partial support for the Trivers-Willard hypothesis, but, more important, we find it has untapped potential in explaining why parents might disagree with each other regarding investment in daughters and sons. A richer understanding of why parents might disagree when making investment decisions is likely only when evolutionary biologists, economists, and anthropologists combine efforts. This study is a step in that direction.

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