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Evolutionary Demography and Intrahousehold Time Allocation: School Attendance and Child Labor Among the Okavango Delta Peoples of Botswana

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ABSTRACT The ways in which resources are allocated within households and/or families, especially within the context of children's time allocation to labor and schooling, has long been a subject of concern to demographers and economists. Differential investment in children and resulting differences in activity budgets may have significant effects on children's growth and development as well as on aspects of reproduction. This study uses predictions regarding parental investment in the embodied capital of offspring generated by evolutionary theory to examine the pattern of children's time allocation to labor and schooling among the Okavango Delta Peoples of Botswana. Models incorporating individual costs and benefits of resource allocation, conflicts of interests between men and women and between parents and offspring, and the effects of family composition, subsistence ecology, and gender are developed and applied to data on time allocation, household demography, and household economy. Several findings emerged: (1) The availability of alternative productive tasks strongly affects intra- and intergenerational labor substitution. (2) The presence of similarly aged children of the same sex within the household decreases the likelihood of both boys and girls engaging in a specific productive activity and increases the likelihood of children's school attendance. (3) Birth order, the labor needs of the household, and parents' marital status all affect school attendance. These results have implications for understanding the determinants of children's time allocation to labor and schooling and consequent impacts on development, health, and welfare. Am. J. Hum. Biol. 14: 206–221, 2002.

The ways in which resources are allocated within households and/or families, especially within the context of children's time allocation to labor and schooling, has long been a subject of concern to demographers and economists (Cain, 1978, 1980; Caldwell, 1976; Grootaert and Patrinos, 1999; Haddad et al., 1997; Kimhi, 1996; Mueller, 1976; Nag, 1972, 1981; Nag et al., 1978; Skoufias, 1993; Udry, 1996). Policy makers recognize that variation in children's time allocation across societies has major implications for societal productivity and human capital, gender equality, and child health and welfare (see Udry, 1996). Of particular interest to human biologists are the ways in which differential access to resources within the household and variation in activity budgets impact growth and development of children. Evolutionary theory generates models of intrahousehold resource allocation, which provide new insights and perspectives on these issues. This paper uses data on children's school attendance and labor among the Okavango Delta Peoples of Botswana to examine intrahousehold resource and time allocation from an evolutionary perspective.

Evolutionary theory and interindividual conflicts

Modern biology recognizes that adaptations are the result of non-random differential reproduction of individuals due to the action of selection on phenotypes (Hamilton, 1964; Williams, 1966). Because it is these individual differences in reproduction and in phenotype-design that produce adaptations, evolutionary approaches to population focus on the effects of individual behaviors and outcomes rather than exclusively on population-level phenomena (Low, 1993). Rather, population-level characteristics are the result of feedback between these individual micro-level events and macro-level processes (Hill, 1993). These macro-level processes include not only features of the physical environment but also

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social institutions and culturally transmitted shared systems of meaning and belief (Irons, 1997a, 1997b).

Conflicts of interest between men and women. Adaptations operating within the individual evolved in the context of maximizing genetic representation in succeeding generations (Williams, 1966), and as such involve the optimal allocation of energy to reproduction. Males and females may have very different interests with regards to individual allocation of resources to an offspring based on the differential payoff to parental investment (Trivers, 1972). In internally gestating species, females are obligated to invest more heavily in offspring through pregnancy and lactation; after birth the level of male parental investment varies widely across taxa. This is due to the varied effects of male parental investment in different ecological contexts as well as the different levels of paternity confidence males, experience in different mating systems (Trivers, 1972).

Human males, in general, invest at a higher level than other primates, indicating that human males experience a greater payoff to their investment than the other primates, possibly due to the greater capacity for learning and extended period of returns for offspring through the human life course (Kaplan, 1997). Hawkes et al. (1998), however, have provided support for an alternative interpretation of male reproductive behavior arguing that men invest in their offspring at low levels similar to that of other primates. Still, there is great variation across and within societies in the level of parental investment by men, and the levels observed represent an accommodation of the differential reproductive interests of men and women. Evolutionary approaches bring to the study of human population the understanding that in addition to focusing on individual-level processes, the reproductive interests of men and women may be quite disparate, and accommodation of those diverse interests arises through bargaining processes modeled via game theory (Maynard Smith, 1982).

Conflicts of interest between parents and children. Similarly parents and offspring may have diverse interests with regard to investment in reproduction (Trivers, 1974). It would be expected that the interests of a parent and its offspring in the pattern and level of parental investment would be congruent only insofar as they are unified with respect to maximizing the parent's genetic representation in succeeding generations. A parent faced with diminishing fitness returns on investment in a particular offspring can be expected to reallocate resources towards investment in other offspring if the marginal return in grandchildren would be higher (Kaplan et al., 1995; Pennington and Harpending, 1988). From the offspring's perspective, however, continued investment could be applied to its own reproductive interests.

This insight argues strongly for a psychology of parental investment in humans that is less interested in maximizing investment in any one child, but rather for parents to be willing to invest at lower than optimal levels in a particular child (from that child's perspective) to maximize returns across the totality of their reproduction (Bock, 1995, 1998, 1999; see Parsons and Goldin 1989 for an analogous argument from microeconomic theory). Parents faced with an action detrimental to one child but advantageous in the sum of their reproductive interests can be expected to pursue that action. Rather than expecting parents to do what is best for an individual child, an evolutionary approach counsels that parents will do what is best for the totality of their own reproductive interests. It may be true in some ecological circumstances where fertility is relatively low and investment is relatively high that parents invest heavily in each child and the interests of parents and children are largely congruent, such as among middle and upper class families in western industrialized societies. However, the ethnographic and historic evidence strongly suggests that parents often sacrifice individual children to further their own reproductive interests through practices such as child factory labor in the developing world or child mining in 19th century Britain and the United States.

Intraindividual resource allocation

Human evolutionary ecologists have used theoretical developments in evolutionary biology to understanding how individuals use resources for reproduction with important implications for the study of human demography. Holding all other variables constant, increases in fertility increase fitness. There are two trade-offs affecting natural selection on fertility that have been formally modeled by life history theorists (Lessells, 1991; Roff, 1992; Stearns, 1992; Charnov, 1993; Hill and Hurtado, 1995). These are trade-offs between present and future reproduction and trade-offs between number and quality of offspring.

The trade-off between present and future reproduction is manifested in the amount of time and resources organisms devote to growth. Growth is a way for organisms to increase the amount of energy they capture in the future, and that energy can then be used for reproduction (Williams, 1966). The juvenile period is characterized by the absence of fertility until reaching a threshold size after which a unit of energy allocated to reproduction has a greater effect on fitness than allocating that same unit of energy to growth (Charnov, 1993). In considering the second trade-off between number and quality of offspring, quality is defined as investment affecting offspring survival and reproduction. Natural selection should result in investment tactics that maximize the number of offspring who survive to reproduce (Smith and Fretwell, 1974).

There is substantial evidence that natural selection has resulted in physiological and behavioral flexibility in age at first reproduction and the rate of reproduction. These adaptations closely follow variation in ecological conditions. Because adaptations related to phenotypic plasticity are so widespread across taxa, there is reason to believe that humans possess similar behavioral and physiological adaptations allowing facultative responses to ecological conditions in life history traits such as age at first reproduction and reproductive rate (see Kaplan and Bock, 2001a).

Kaplan and colleagues (Kaplan, 1996; Kaplan et al., 1995, 2000; Kaplan and Bock, 2001a) have proposed a theory of human life history evolution based on returns to investment in embodied capital. This theory integrates human capital theory in economics with life history theory from evolutionary biology by treating the processes of growth, development, and maintenance as somatic investments. Investment in embodied capital has two aspects, the physical and functional. The physical payoff to investment in embodied capital is the actual tissue involved. The functional payoff to investment in embodied capital is manifested in qualities such as strength, immune function, coordination, skill, knowledge, and other abilities (see Kaplan et al., 2000). These attributes continually diminish in response to metabolic activity and aging, and as a result energy allocation to cell maintenance can also be seen as investments in embodied capital (Kaplan et al., 2000). As a result, the present versus future reproduction trade-off is a form of optimal investments in own embodied capital versus using those resource for reproduction, and the number versus quality trade-off is a function of investment in the embodied capital of offspring (Kaplan and Bock, 2001a).

Intrahousehold and intergenerational resource allocation

Demographers and human evolutionary ecologists interpret observed patterns of intrahousehold and intergenerational resource allocation differently. Demographers tend to see cross-cultural variation in these patterns as either random or as a reflection of cultural norms and traditions. Human evolutionary ecologists view this variation as the outcome of different solutions to the two central life history trade-offs based on differing ecological context. In this way, resource allocation across individuals is a matrix of allocation decisions within each individual shaped by interindividual conflicts.

The wealth flows theory of Caldwell (1982) has become accepted conventional wisdom within demography and other fields. The theory proposes that fertility decisions in all societies are economically rational responses to familial wealth flows. In societies with net upward wealth flows such as among peasant farmers, individuals are expected to have as many surviving children as biological constraints permit. Each offspring potentially provides additional wealth, old age security, and/or socio/political status. In societies with net downward wealth flows such as Western industrial society, individuals are expected to severely limit their reproduction. According to Caldwell (1982), the worldwide transition from high to low fertility is the result of changing family structures from upward to downward wealth flows. Educational systems inculcate an individualistic value system that replaces the corporate family oriented values and result in downward wealth flows (Caldwell, 1980). At some point mass education is expected to reach a threshold where individualistic value systems predominate with concomitant low fertility.

Anthropologists and other scientists using an evolutionary perspective have mounted the most serious challenge to the wealth flows theory. Several have argued that evolutionary biology predicts that net wealth flows should be downward in all organisms, which casts doubt on the viability of the system described by Caldwell (Kaplan, 1994; Low, 1993; Low et al., 1992; Turke, 1989, 1991). Many studies that have attempted to test wealth flows theory do not measure the absolute flow of wealth but rather indicators of changes in the economic contributions of children. Studies that have actually measured the net flow of wealth in high fertility societies do not support a strict interpretation of the theory (Kaplan and Bock, 2001b).

The present study examines the pattern of time allocation to productive activities and school in children within a traditional economy in light of intraindividual allocation trade-offs as well as competing and conflicting individual interests with regard to household level resource allocation. Several features of household composition and economy are hypothesized to affect the activity profile of children. Because these interests are strongly gendered, the analytical framework used incorporates this gender distinction.

METHODS

The study community

The hypotheses were examined using data collected in a multi-ethnic community in the Okavango Delta of northwestern Botswana (see Bock, 1995, 1998; Bock and Johnson, 2002). Five ethnic groups are represented: Hambukushu, Dxeriku, Wayeyi, Xanekwe, and Bugakwe. Hambukushu, Dxeriku, and Wayeyi people are Bantus who inhabit the Okavango River drainage from Angola through the Caprivi Strip of Namibia into northern Botswana. Historically, they have participated in mixed economies of farming; fishing, hunting, and the collection of wild plant foods; and pastoralism. Xanekwe and Bugakwe people are San speakers who inhabit the Okavango drainage in Namibia and Botswana. Xanekwe have historically had a riverine orientation in their foraging, whereas Bugakwe have been savanna foragers. The Xanekwe living in the study community practice a mixed economy, but farm at a much less intensive level than the Bantus. Moreover, among 50 Xanekwe there were only four head of cattle, whereas a typical Bantu homestead of 20 people had an average of 12 head. Bugakwe in this community are largely oriented towards fishing, hunting, and the collection of wild plant foods. None owned cattle, and their agricultural fields were very small. No Bugakwe people are included in the study of grain processing.

At the time of the study, there was very little cash economy in the community. Most men of all ethnic groups over the age of 35 had worked in the mines of South Africa for an average of 4 years. Proceeds from this labor were largely used to purchase clothes, consumer goods, or cattle. Many of the Xanekwe and Bugakwe men over the age of 25 had been soldiers in the South African Defence Force during the bush wars of the 1970s and 1980s. Few women, however, had ventured beyond the next community 30 km away. There was no school, clinic, or borehole, with water drawn from a river source. Of 122 children in 1992, 20 attended school. Of those, 15 attended a primary school in the next community, walking the 30 km to school on Sunday and home again on Fridays. Five children attended secondary school in larger towns.

This community offered several important qualities as a field site. There was an extremely limited cash economy, a low rate of school attendance, and great economic diversity. The lack of a cash economy made measurement of household productivity possible. The low rate of school attendance meant that most children could be observed, allowing for exploration of their role in household and family economy. Last, the economic diversity meant that children's and adults' time allocation as well as parental investment in the embodied capital of offspring could be examined across a number of traditional economic pursuits.

Data collection

Three types of data were used: behavioral observations, household demographic data, and household economic data. The behavioral observation data consisted of instantaneous scan samples collected over the course of 11 months in 1992. Extended family homesteads were sampled on a rotating basis repeatedly over three 4-hour periods, 6:00 AM 10:00 AM, 10:00 AM to 2:00 PM, 2:00 PM to 6:00 PM, that roughly corresponded to the daylight hours. On an hourly time point, the activity, location, and interactants of all residents of the homestead were noted. For residents who were not present, other residents were asked for that person's activity and location, and this information was verified with the focal subject either upon his or her return or later. In addition, the commodity, amount, producer or collector, and recipient of all food brought into the homestead were recorded.

Interviews regarding household and family demography and economy were conducted in 1992 and 1994. An initial census was conducted asking who resided in each house within each homestead. In addition, data were collected on people who were occasional residents or who were considered residents but were currently elsewhere. The head of the household was then asked how each of these people was related to him or her. Reproductive histories were also collected for all men over 20 and all women over 16. These data were cross-checked with the census data. Both the census and reproductive history data have been regularly updated since 1992. On a monthly basis, each head of household was asked about non-monetary and monetary resource flow into the household. He or she was asked what resources including cattle were acquired, by whom, and from whom. These data, combined with the acquisition data collected during the homestead instantaneous scans, provided an accurate picture of resource flow. To establish the level of storable resources, a cattle census was conducted for each homestead in 1992, and the entire harvest production for each household in 1992 was measured.

Data analysis

The data were analyzed using multivariate probit models incorporating time varying covariates (Greene, 1993) that are appropriate for time allocation data consisting of point samples with comparatively rare events and random effects (Kimhi, 1996). In these models, the dependent variable is a binary outcome indicating that an event was observed or not. Goodness of fit was assessed using the maximum log likelihood method (Diggle et al., 1994). All analyses were conducted using SAS 6.08.

HYPOTHESES REGARDING CHILDREN'S TIME ALLOCATION

Activities of children have potential value to the child concerned and to his or her parents. This can be in the form of increased accruable wealth, effects on the reproductive status, fertility, mortality of other family members, and effects on the child's future success in terms of economic attainment, mate choice, and fertility. Parents can manipulate a child's time allocation to different activities in an attempt to maximize the return on investment across children. It is expected that this manipulation will occur in the trade-off in a child's time budget between non-productive activities that may have a return in the future in the form of experience-based embodied capital such as skill acquisition or formal education and productive activities to which there is an immediate return (Bock, 1995, 2002).

The kinds of short- and long-term costs and benefits that this hypothesis predicts will be important are those affecting immediate production and skill acquisition (Bock, 1995, 1999). In the short term, if children work, their labor will produce resources that may be used to increase the child's growth-based embodied capital or probability of survival or to assist other related individuals. The short-term costs are in opportunity cost loss of income from other productive tasks. The long-term benefits of children's time allocation to productive tasks are in the possible experience-based embodied capital acquired during the performance of that labor. The long-term costs are to the opportunity to acquire other skills.

This means that parents are motivated to manipulate children's time differentially into productive activities and skill acquisition activities. The hypotheses recognize the inherent potential conflicts of interests between children and parents with regard to children's time allocation. It is also important, however, to realize that in many circumstances there is a power imbalance between children and parents with regard to activity choice. In the study community, parents exercise a considerable amount of coercive control over children's time (Bock, 1998, 1999, 2002). Because the mix of productive and skill acquisition activities is expected to vary from child to child, the knowledge and skills embodied in a particular child will vary as well. Based on the costs and benefits in the long- and short-term to each child and his or her parents, children are expected to experience considerable variation in their daily activities, experiences, and in the skills and knowledge embodied within them.

Boys' productive activities

Boys (4–18 years of age) in the study community engaged in three main forms of labor that contribute to the household economy: herding, milking, and domestic chores. Family herd size indicated by the number of head of cattle is hypothesized to increase the probability of herding. The number of available substitute laborers should decrease it. Father's absence should increase the amount of herding. An interaction effect is predicted between father's absence and number of head. If father is absent, but has a large herd, then the sons are expected to be even more likely to be observed herding than if a father is present with the same size herd. Boys 10 to 15 years should be more likely to be observed herding. Because more boys are likely to be home from school on the weekend, overall the probability of being observed herding should increase from Friday afternoon to Sunday noon. As cattle in this community go into the bush in the morning without active human participation, it is expected that boys will be more likely to herd later in the day. Lastly, boys who attend school away from the community should be less likely to be seen herding.

The probability of boys being observed milking is expected to be positively affected by factors similar to herding including the herd size, the presence of labor substitutes, father's absence, whether the boy is in the most likely age class for milking, and whether the observation took place on the weekend. The availability of substitute labor as well as school attendance should make the boy less likely to be observed milking. Because milking occurs when calves are let in their mother's corral at dawn, later hours of the day should have a negative effect.

The probability of being observed in domestic labor (cooking, fire building, firewood and water collecting and carrying, and washing) for boys ages 4 to 18 years should be strongly influenced by the labor needs of the household. It is expected that mean daily agricultural calories available would have an effect on the amount of cooking, washing, and need for water and firewood. Also, most domestic labor should take place later in the day, as that is when the wash water and firewood must be available. Although there is no significant effect of age on the time allocation to domestic labor for boys (Bock, 1995), age was controlled for in each test to ensure that the age effect was not obscured by heterogeneity. It is predicted that domestic labor would be more likely on weekends. Boys who attend school were expected to devote more time to domestic labor, because they devote less time to herding. For both boys and girls, it was predicted that children under 10 years would be less likely to substitute for domestic labor and that older children would be more likely to substitute.

Girls' productive activities

The majority of labor contributions of girls to the household economy are grain processing, domestic labor and child care (through freeing mothers' and other adult women's time). The availability of agricultural products is expected to have a positive effect on the probability of girls being observed processing grain. In 1992, millet was the predominant grain crop and, due to drought, there was a great deal of variation in millet availability across households. For that reason, the availability of grain is measured as the mean daily caloric value of millet in storage. This is expected to have a positive effect on the probability of being observed in agricultural activities. Time spent processing grain peaks at age 14 years, and then shows a slight dip when many girls are away at school (Bock, 2002). The availability of this substitute labor is predicted to have a negative effect on the probability of observing a girl processing grain. Since it was assumed that girls of that age group are more likely to process, an age control dummy variable is included which indicates whether girls belong to the age class 10 to 14. This variable is expected to have a positive effect. As with boys, hour of the day is included because that most domestic activities take place later in the day. School attendance should have a negative effect. Time of year is also expected to affect the probability of grain processing because the millet harvest occurred in the months of April and May and grain processing would be more frequent at this time of abundance.

The probability of being observed in domestic labor for girls is expected to be influenced by features of both subsistence ecology and family and household needs. The amount of cooking, fire building, firewood and water collecting and carrying, and washing is expected to increase with food availability measured as the mean daily caloric value of stored millet. Because girls 10 to 18 years are the most common participants in domestic labor activity, a labor substitution effect of their labor for other girls' should be seen, and this should serve to decrease other girls' domestic labor. As with boys, the time of day, day of the week, and time of year are expected to affect the probability of a girl being observed in domestic labor. Girls who attend school are expected to be less likely to be observed in this activity.

Child care is the third most common labor activity for girls and is primarily performed by girls 8 to 18 years. The number of children under 4 years of age is expected to have a positive effect on the amount of child care to be done. The number of substitutes, however, should have a decreasing effect. In this case it is predicted that the number of girls 10–14 years will decrease the probability of being observed in child care. A dummy variable indicating whether the girl is between 10 and 14 years should have a positive effect on child care, i.e., 10 to 14 year old girls are predicted as being more likely to be observed in child care. It is predicted that child care will be observed by girls earlier in the day. This is because if women are in the fields or in the bush, their daughters may be substituting. Girls who attend school are predicted to be less likely to be observed in child care. It is expected that girls are more likely to be observed in child care on the weekend. Lastly, if girls are substituting labor for their mothers', then girls are more likely to be observed in child care during harvest time, when mothers' labor is taken up in agricultural activities.

School attendance for boys and girls

The factors that affect school attendance away from the community are expected to differ for boys and girls. Because number of cattle is a major source of both traditional and modern wealth, it is expected that the number of cattle owned by the boy's parents will have a positive effect on school attendance. The firstborn son is predicted to be more likely to attend school. The availability of substitutable labor here is a positive effect. Boys in the age range 7 to 15 year should substitute for another boy's labor, making it more likely that the elder can attend school without causing a labor deficit. There is predicted to be a negative effect of father's absence on school attendance. Boys with absent fathers are predicted to be less likely to attend school. An interaction effect is predicted between father's absence and number of head. Number of head of cattle should have less of an effect for boys whose fathers are absent than for boys whose fathers are present. School attendance is predicted to be more likely among boys 15 and over.

In this predominantly polygynous community, most men have two wives. Men may be allocating resources not only in the accommodation of the two central life history trade-offs but also within the context of interindividual conflict. This expectation leads to the prediction that men would bias investment towards the children of their senior wives with the junior wives' children, in effect, subsidizing that investment through labor as opposed to education. Children of senior wives, controlling for other factors, should be more likely to attend school than children of junior wives.

For girls as well as boys, parental resources, in terms of number of head of cattle, are expected to have a positive effect on the

TABLE 1. Determinants of time spent herding by boys

Independent variable	Parameter estimate	Standarized estimate	Partial *p*	Contribution to W with 1 d.f.	W>chi-square, 1 d.f.
Head of cattle	0.0224	0.128555	<0.0001	17.365	<0.0001
Number of coresident boys ages 10–14	−0.3027	−0.183500	<0.0001	13.677	0.0002
Father absent	1.0052	0.166514	0.0003	28.437	<0.0001
Father absent* Head of cattle	0.0555	0.195575	<0.0001	30.995	<0.0001
Age 10–14 dummy	0.2717	0.134188	0.0061	7.542	0.0061
Time of day	0.0470	0.165323	0.0010	11.11	0.0009
School attendee	−0.3586	−0.053502	0.0049	7.893	0.0052
INTERCEPT	−2.0213		<0.0001	888.129	
Total of final reduced model				814.846	

*Reduced model from probit regression. Goodness of fit was assessed using the maximum log likelihood method. Weekend observation was eliminated from the original full model.

probability of attending school. As with boys the oldest daughter is expected to be more likely to be reported attending school. The more labor substitutes present, measured here as the number of girls between 10 and 14 year, co-resident, the more likely a girl is to attend school. Agricultural production, here measured as the mean daily caloric value of stored agricultural products, is expected to have a negative effect on girls' school attendance, because we know that girls' work is dependent on agricultural production. The seniority status of the girl's mother is expected to have a positive effect. That is, if there are different human capital investment trajectories for children born of senior and junior wives, we should expect the children of senior wives to be sent away to school. Last, we should expect less school attendance at harvest time, as girls' labor may be needed more at this time than at others.

Labor substitution effects

The effects of household economy and composition on children's activities have major implications for the overall distribution of labor within the household (Skoufias, 1993; Bock, 1995, 1999, 2002; Liu, 1999; Grootaert and Patrinos, 1999). Substitution of labor can occur between children and across generations between parents and children. If two children are equally able to perform one of the available productive tasks, then parents can substitute one child's labor for another. For purposes of simplification, if it is assumed that one child's labor is used to substitute for another, the second child's time is then freed to devote to another activity. This time can be used for acquiring embodied capital or for immediate productivity, and parents must again make an allocation decision based on the costs and benefits. If there is no productive labor in which the child can efficiently engage, then there is no short-term cost to spending that time in embodied capital acquisition other than direct costs of provisioning. Conversely, if there are productive tasks in which that child's labor would produce a greater benefit to the parent, then we would expect that acquisition to be foregone.

The second kind of expected labor substitution would be between parents and children (Skoufias, l993; Bock, 1995, 1999, 2002; Liu, l999). If there are activities that both a child and a parent can perform equally, then it is expected that the parent will substitute the child's labor for his or her own. This would free the parent to engage in activities in which the child's labor would be worth much less, such as activities for which the child has insufficient ability but the parent is competent. If there are no activities in which a child can engage efficiently, then a parent weighing costs and benefits would have that child engage in skill acquisition with an eye to future benefits.

RESULTS

Boys' time allocation to productive activities

Table 1 is the result of the model test of boys' time allocation to herding. The strongest effects are from father absence and the interaction term between father

TABLE 2. Determinants of time spent milking by boys

Independent variable	Parameter estimate	Standardized estimate	Partial *p*	Contribution to W with 1 d.f.	W>chi-square, 1 d.f.
Head of cattle	0.0212	0.401814	<0.0001	21.990	<0.0001
Age 15–18 dummy	0.6048	0.291814	<0.0001	33.376	<0.0001
Time of day	−0.1446	0.49649	0.0038	9.028	0.0027
INTERCEPT	−1.337		<0.0001	260.462	
Total of final reduced model				218.059	

Reduced models from probit regression. Goodness of fit was assessed using the maximum log likelihood method. Number of coresident boys, weekend observation, father absence, and school attendence were eliminated from the original full model.

TABLE 3. Determinants of time spent in domestic labor by boys

Independent variable	Parameter estimate	Standardized estimate	Partial *p*	Contribution to W with 1 d.f.	W>chi-square, 1 d.f.
Agricultural production	0.000026	0.128555	0.0876	6.0340	0.014
Weekend	−0.3723	−0.183500	0.0281	5.193	0.0227
Time of day	0.0483	0.166514	0.0380	4.366	0.0367
School attendee	0.4833	0.195575	0.0026	8.362	0.0038
INTERCEPT	−0.3723		0.0001	318.557	
Total of final reduced model				295.761	

Reduced models from probit regression. Goodness of fit was assessed using the maximum log likelihood method. Boy's age coresident boys, and coresident girls were eliminated from the original full model.

absence and number of cattle. This suggests that boys whose fathers are away performing wage labor are substituting for some of their father's labor. The next strongest effect was from the number of co-resident boys. This implies that the presence of substitutable labor of the same age group is an important effect determining the probability of being observed herding. Boys 10 to 15 years are more likely to be observed herding, and boys who attend school away from the community are understandably less likely, to herd.

Number of cattle in the family herd has the strongest effect on the probability of boys being observed milking (Table 2). Being from 10 to 18 years increases the probability of herding, as does the time of day. The number of substitute laborers available is a borderline significant effect and is in the predicted direction.

Mean daily agricultural output available has a positive effect on the probability of boys being observed in domestic labor (Table 3). The later in the day, the more likely to be observed in domestic labor, and those attending school are more likely. Boys are less likely to be observed in this activity on the weekend. There is no significant age effect, nor are there any significant improvements to model fit of any of the labor substitution variables.

Girls' time allocation to productive activities

As predicted, the availability of grain has a positive effect on the probability of a girl being observed in grain processing (Table 4). This effect is borderline, however, which may be due to reciprocal arrangements wherein someone without grain barters processing time for some of the processed grain. The labor substitution effect is negative as predicted, meaning that the more girls 10 to 14 years present in the courtyard, the less likely individual girls are to be observed in processing. The age indicator variable is positive, meaning that girls 15 to 18 years are more likely to process. Hour of the day is positive, indicating that grain processing takes place later in the day.

The number of girls 10 to 18 years has a strong negative effect on the probability of being observed in domestic activity, implying that labor substitution is an important determinant of allocation of labor to this activity (Table 5). As expected girls of this age do more of this work. This activity usually takes place later in the day as expected. Contrary to expectation, it is less likely to be observed on the weekend.

School attendance and harvest time are the only variables that had significant effects on the probability of being observed in child care for girls (Table 6). The number of

TABLE 4. Determinants of time spent processing grain by girls

Independent variable	Parameter estimate	Standardized estimate	Partial *p*	Contribution to W with 1 d.f.	W>chi-square, 1 d.f.
Agricultural production	0.000025	0.150606	0.0779	3.399	0.0562
Number of coresident girls ages 10–14	−0.2751	−0.205428	0.0449	4.376	0.0364
Age 15–18 dummy	0.6182	0.242849	0.0051	7.590	0.0059
Time of day	0.1131	0.373072	0.0003	13.400	0.0003
INTERCEPT	−3.2626		<0.0001	257.254	
Total of intercept covariates				225.221	

Reduced models from probit regression. Goodness of fit was assessed using the maximum log likelihood method. Harvest time, school attendance, and weekend observation were eliminated from the original full model.

TABLE 5. Determinants of time spent in domestic labor by girls

Independent variable	Parameter estimate	Standardized estimate	Partial *p*	Contribution to W with 1 d.f.	W>chi-square, 1 d.f.
Number of coresident girls ages 15–18	−0.3094	−0.210947	0.0026	9.34	0.0022
Age 10–18 dummy	0.5490	0.273889	0.0003	13.573	0.0002
Time of day	0.0780	0.250267	0.0012	11.611	0.0007
Weekend	−0.2861	−0.141732	0.0662	3.639	0.0564
INTERCEPT	−3.0412		<0.0001	374.531 (5 d.f.)	
Total of intercept covariates				337.507 (4 d.f.)	

Reduced models from probit regression. Goodness of fit was assessed using the maximum log likelihood method. Harvest time, school attendence, and agricultural production were eliminated from the original full model.

TABLE 6. Determinants of time spent in child care by girls

Independent variable	Parameter estimate	Standardized estimate	Partial *p*	Contribution to W with 1 d.f.	W>chi-square, 1 d.f.
School attendee	−0.7800	−0.361215	0.411	4.928	0.0264
Harvest time	0.9192	0.455673	0.0126	7.160	0.0075
INTERCEPT	−2.6454		<0.0001	111.891 (2 d.f.)	<0.0001
Total of intercept covariates				99.883 (2 d.f.)	

Reduced models from probit regression. Goodness of fit was assessed using the maximum log likelihood method. Number of coresident children, agricultural production, age, and weekend observation were eliminated from the original full model.

children under 4 years has a positive coefficient and the number of substitutes had the predicted negative coefficient, but neither is a statistically significant improvement to the model.

School attendance for boys and girls

Herd size, whether the boy is the first born, and number of coresident boys from 7 to 15 years old all have positive effects as predicted on the probability of boys attending school (Table 7). Father absence has the predicted negative effect. The interaction term between herd size and father absence, which has been significant in other models, did not improve the model fit, although the direction of the effect is as predicted. The boy's age was a major determinant of school attendance away from the community. Whether the boy's mother is the senior wife also did not significantly improve model fit, although again the direction of the effect is as predicted.

As expected, size of the parents cattle herd has a positive effect on school attendance for girls (Table 8). The number of substitute laborers, however, has a negative effect, in contrast to the prediction; for boys, this effect is positive. One possible implication is that girls compete for the chance to attend school, whereas for boys the oldest boy whose labor would be surplus is sent. As expected, girls 15 year and older are more likely to attend school. Agricultural production decreases

TABLE 7. School attendence by boys

Independent variable	Parameter estimate	Standardized estimate	Partial *p*	Contribution to W with 1 d.f.	W>chi-square, 1 d.f.
Head of cattle	0.0377	0.465329	<0.0001	83.76	<0.0001
Oldest child dummy	1.2715	0.589100	<0.0001	130.332	<0.0001
Number of coresident boys age 10–14	0.2742	0.221165	<0.0001	21.498	<0.0001
Father absent	−1.0511	−0.518243	<0.0001	122.784	<0.0001
Age 15–18 dummy	1.2307	0.58226	<0.0001	86.542	<0.0001
Intercept	0.2988		0.0301	122.602 (5 d.f.)	
Total of intercept covariates				829.589 (5 d.f.)	

Reduced models from probit regression. Goodness of fit was assessed using the maximum log likelihood method. Interaction of father absence and herd size and child of senior wife were eliminated from the original full model.

TABLE 8. School attendence by girls

Independent variable	Parameter estimate	Standardized estimate	Partial *p*	Contribution to W with 1 d.f.	W>chi-square, 1 d.f.
Head of cattle	0.1002	2.078991	<0.0001	54.945	<0.0001
Number of coresident girls ages 10–14	−4.9424	−3.138780	<0.0001	114.999	<0.0001
Age 15–18 dummy	11.8192	5.788622	<0.0001	340.167	<0.0001
Agricultural production	−0.00043	−2.719269	<0.0001	153.216	<0.0001
Oldest child dummy	−2.9676	−1.433705	<0.0001	40.518	<0.0001
Child of senior wife	1.9903	0.808463	<0.0001	35.64	<0.0001
INTERCEPT	−1.8320		0.0060	896.854 (6 d.f.)	
Total of intercept covariates				640.307 (6 d.f.)	

Reduced models from probit regression. Goodness of fit was assessed using the maximum log likelihood method. Harvest time was eliminated from the original full model.

the likelihood of school attendance, as expected. Contrary to the expectation, oldest daughters are less likely to attend school. This may be because girl's labor is more skill dependent than boys, and the oldest daughter is a valuable labor addition to the household. Daughters of senior wives are also more likely to attend school.

DISCUSSION

Parental investment in the embodied capital of offspring varies as a function of subsistence ecology and family composition. This variation is manifested through the pattern of productive activities for boys and girls, and particularly in the ways in which the time children spend in different activities is related to the efficient allocation of household resources. Moreover, variation in parental investment is reflected in the influence of household labor needs on the patterning of school attendance.

Labor substitution across productive activities

The differential allocation of time to productive activities is strongly affected by the sex- and age-dependent ability to perform tasks successfully (Blair, 1992; Bock, 1995, 1998, 2002). This distribution of age- and sex-dependent task performance ability interacts with household labor needs and family composition. For boys, the overall pattern exhibited is substitution across age class to others for herding, milking, and all productive labor (Table 9). Herding is an activity performed by younger boys, and milking is a task for older boys. Time allocation to these productive tasks has strong interactions with school attendance. Boys who attend school are significantly less likely to herd than boys who do not attend school, and boys who do attend school are significantly more likely to be observed in domestic labor. In addition, the number of co-resident boys in the 6 to 14 age class significantly increases a boy's school attendance. This indicates that the allocation of parental investment across the sibship is heavily dependent on the amount of herding labor available.

Intergenerational substitution patterns between boys and men are more difficult to interpret. Substitution for activities in

TABLE 9. Labor substitution effects by activity for males

Activity	Substitute age classes	School effect	Significant effects across or within age class
Boys			
Herding	6–14	Negative	Decrease
Milking	10–18	Positive (NS)	Boys not attending school decrease for boys attending
Domestic labor	None	Positive	Decrease
School	6–14		Boys not attending school decrease for boys not attending
Men			Increase for boys 15–18
Herding	10–14		Decrease
Hunting	6–18		Decrease
Craft work	6–18		Increase
Garden labor	10–14		Decrease

The substitute age class indicates the age group of boys who engage most in this activity. Boys who attend school are significantly less likely to herd than boys who do not attend school, and boys who do attend school are significantly more likely to be observed in domestric labor. This leads to significant age effects within age class. The presence of boys in the substitute age class as a significant negative effect on the probability that on individual boy or man will engage in any particular activity except for a school and craft labor. Substitute labores increase the likelihood a boy will attend school. The increase in craft work may be due to the extreme skill requirements of craft work.

TABLE 10. Labor substitution effects by activity for females

Activity	Substitute age classes	School effect	Significant effects across or within age class
Girls			
Grain processing	10-14	Negative (NS)	Decrease
Domestic labor	10-18	Negative (NS)	Decrease
Child care	10-14 (NS)	Negative	Girls attending school decrease for girls not attending school
School	10-14		Decrease
Women			
Grain processing	none		None
Domestic labor	none		None
Child care	15-18		Decrease
Craft work	none		None
Garden labor	none		None
Collecting wild plant foods	6-14		Increase
Mongongo processing	none		None

The subsitute age class indicates the age group of girls who engage most in this activity. Girls who attend school are significantly less likely to perform child care than those who do not attend school. This leads to significant age effects within age class. The presence of girls in the substitute age class has a significant negative effect on the probability that an individual girl or woman will engage in grain processing, domestic labor, or child care. Substitute laborers increase the likelihood a girl will attend school. The increase in wild plant food collection may be due to the extreme skill and knowledge requirements of this activity which lead to strong positive age-dependence.

which boys can perform as well as men such as herding is expected. The number of co-resident boys 10 to 14 year decreases the amount of herding for adult men, indicating that there is some labor substitution for that activity as expected. The number of boys in each age class has a separate positive effect on craftwork. This can be interpreted as a substitution effect across activities; i.e., boys are engaging in some activities that free men's time for craft work. Two other substitution effects, however, are contrary to the theoretical expectation. First, the number of co-resident boys 10 to 14 year decreases the amount of garden labor for men. Second, the number of boys in each age class, 6 to 18, has a negative effect on the probability of a man being observed hunting.

For females, there are substitution effects for both grain processing and domestic labor of girls 10 to 14 years old (Table 10). School attendance by girls represents a significant loss of labor, and school attendance has a negative effect on time allocation to every other activity. It was expected by other girls substitute labor, so that an increase in the labor supply increases a girl's chances of school attendance away from the community. Instead, the number of girls in the age class that does the most work, 10 to 14 years, decreases the probability of a girl going to school. This suggests that there is more competition across girls for school attendance.

Substitution between girls and women for grain processing and domestic labor and child care was effected. Collecting wild plant foods is an activity often done by groups of women and girls, and this should mitigate against seeing a substitution effect even though on the basis of age-specific skill and return rate, are would be predicted. Substitution of girls' labor for adults for mongongo nut processing, garden labor, or craft work was not affected. Contrary to the prediction, there is no substitution effect between girls and women in grain processing or domestic labor. A possible explanation is that girls are doing these activities at their maximum rates and that when women engage in them it is to handle an overflow. There is evidence for a substitution of labor across child care by girls 15 to 18 years, as predicted. There are no effects, as expected, of substitution of labor in craft work, garden labor, or mongongo nut processing. Finally, there is a positive effect of the number of girls 6 to 14 years on the amount of time spent in wild plant food collection. This implies some substitution across activities, and it may be that the amount of grain processing and domestic labor done by girls frees women to do this activity more.

Several macro-level studies have found similar effects with regard to intergenerational substitution of labor in females (Blair, 1992; Skoufias, 1993; Grootaert and Patrinos, 1999; Liu, 1999). No prior studies, however, have examined the effect of intragenerational labor substitution among children nor have any examined intra- or intergenerational labor substitution among males. The focused micro-level study presented here has the additional benefit of directly relating household level labor attributes and needs to time allocation through direct observation. Moreover, because school attendance was measured on a daily basis, the implicit trade-off between investment in embodied capital and immediate productivity (Becker, 1965; Bock, 1995, 2002; Kaplan, 1996) was directly measured.

School attendance

Several studies have reported a trade-off between child labor and schooling (see Grootaert and Patrinos, 1999). Most of these studies, however, have not differentiated between forms of productive activities, household versus commercial labor, or gender differences (Ilahi, 2000). The present study demonstrates a gender bias school attendance that is related to the labor requirements of households. As families rely more heavily on agriculture, girls are less likely to attend school, because the payoff to parents would be higher if a girl stayed home and contributed to household productivity. As families rely more heavily on herding, boys are less likely and girls more likely to attend school. People in this multi-ethnic community are involved in mixed subsistence ecologies of fishing, farming, foraging for wild plant foods, hunting, and herding. The male and female labor requirements as well as the ability of children to contribute to household productivity vary as a function of the type of mixed subsistence ecology specific to a household. When families rely heavily on foraging, children can contribute comparatively little. When families rely heavily on agriculture or herding, children can make a relatively large contribution, with boys' labor more important to herding and girls' to agricultural pursuits. These findings are parallel those of several studies of sub-Saharan African populations in mixed economies (Reynolds, 1991; Lancy, 1996).

Firstborn girls are far less likely to attend school than other members of their sibships, whereas firstborn boys are far more likely. This is due to the differential benefits of the labor of teenage girls and boys to parents. Teenage girls can contribute to the household through childcare, domestic labor, and certain kinds of subsistence activities, especially agricultural labor. By doing this a teenage girl's labor is substituted for that of an adult woman, freeing the woman to engage in more profitable activities such as fishing or collecting and processing mongongo nuts. The labor of teenage boys, on the other hand, is much less easily substitutable for that of adult men. Adult men engage in a number of difficult, high skill tasks such as hunting, fence building, canoe building, and various forms of craftwork.

Children are also more likely to attend school when there are other boys or girls of close age in the household. When there are multiple children of the same sex and similar age a family may have more labor capacity for certain tasks than can be efficiently allocated. The result is that some children's time is bringing no immediate return to parents. Investing that time in education, however, may bring a long-term payoff (Bock, 2002).

Daughters of senior wives of polygynously married men are significantly more likely to attend school than daughters of junior wives. This same relationship does not hold true for boys. Boys, however, are far less likely to attend school if their father was working outside the community, for instance in the South African mines. These differential effects are indicative of the different household labor requirements for male and female labor. Senior wives are more able to substitute someone else's labor, possibly the daughter of a junior wife, for that of her own daughter selected to attend school. When a father was absent, however, the labor of boys is needed to substitute for that man's labor.

An evolutionary perspective on investment in embodied capital of offspring leads to the integration of individual costs and benefits, conflicts of interest between men and women, and gender-biased parental investment into models of children's time allocation. These holistic models have provided an analytical framework that sheds new light on the effect of household economy and family composition on children's time allocation.

SUMMARY

In this study a number of predictions concerning differential patterns of parental investment due to subsistence ecology, offspring gender, birth order, family characteristics, and parental characteristics were generated from evolutionary theory. These predictions were based on the potential payoff of investment in children to parents. Three main findings emerged regarding children's time allocation to labor: (1) A crucial determinant of the effect of labor substitution is the availability of alternative productive tasks. (2) The presence of similarly aged children of the same sex within the household decreases the likelihood of both boys and girls engaging in a specific productive activity. (3) In this community, boys' labor is more easily substitutable for men's than girls' labor is for women's.

Six main findings emerged regarding children's school attendance: (1) Variation in parental investment is reflected in the influence of household labor needs on the patterning of school attendance. (2) Gender bias in school attendance is strongly related to the labor needs of the household. These labor requirements are related to parents' reproductive interests. (3) Birth order affects school attendance differently for boys and girls. Firstborn girls are less likely to attend school than girls born later, whereas firstborn boys are more likely to attend school than their later born counterparts. (4) The presence of similarly aged children of the same sex within the household increases the likelihood of children's school attendance. This is due to substitution of labor for specific activities. (5) Daughters of polygynous men are more likely to attend school if their mothers are senior wives. There is not effect of polygyny on boys' school attendance. (6) When fathers are engaged in migratory labor boys were less likely to attend school. There is not effect of father absence on girls' school attendance.

Perhaps most significant for policy implications is that whether or not a specific child would benefit from attending school was not a significant predictor of school attendance. Rather, the degree to which parents' own reproductive interests were served was the primary predictor of which children attended school. Without a basis in evolutionary theory and these kinds of data, the relationships described above would have remained elusive.

The results contribute to the understanding of the interaction of subsistence ecology, family composition, and gender on children's time allocation to labor and schooling. They highlight the benefits to using micro-level, longitudinal data that incorporate behavioral observation, and direct measurement. Moreover, this study represents an example of the value of new theoretical developments in human evolutionary ecology when applied to the study of child and family demography.

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