VARIATION IN JUVENILE DEPENDENCE
Helping Behavior among Maya Children

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Notable in cross-cultural comparisons is the variable span of time between when children become economically self-sufficient and when they initiate their own reproductive careers. That variation is of interest because it shapes the age range of children reliant on others for support and the age range of children available to help out, which in turn affects the competing demands on parents to support multiple dependents of different ages. The age at positive net production is used as a proxy to estimate the close of juvenile economic dependence among a group of Maya subsistence agriculturalists. Maya children produce more than they consume by their early to mid teens but remain in their natal households for a number of years before leaving home and beginning families of their own. The Maya results contrast markedly with those from several groups of hunter-gatherers and horticulturalists for whom we have similar data. Even in the Maya case, where children are self-sufficient at a relatively young age, parents are unable to support their children without help from others. The production surplus of older children appears to help underwrite the cost of large Maya families and subsidize their parents' continued reproduction.

KEY WORDS: **Children's work; Family size; Juvenile dependence; Maya; Time allocation**

Because of the prolonged period of human maturation, when a child is born parents must care for the newborn while continuing to support their

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older children. Consequently, one of the fundamental trade-offs human parents face is having to support multiple dependents of different ages. If the age at which children become self-reliant varies, that variation affects the competing demands on parents to provide child care to young children and food, resources, and other services to older children, a trade-off that constrains the number of children parents can successfully raise. The timing of children's economic independence influences the parents' time and resource budgets in two important ways. First, in most animal species, juveniles become self-sufficient before or at sexual maturity, but among humans this may or may not be the case. When older children are able to support themselves, parents have a greater available budget to care for younger children if they so choose. Second, the production surplus of older children can be transferred to help subsidize dependents, allowing parents to raise more children than they might otherwise be able to do. Offspring as helpers in the nest have been studied among both humans and nonhumans (Crognier, Baali, and Hilali 2001; Emlen 1984; Emlen et al. 1991; Krebs and Davies 1997; Turke 1988, 1989), but the ends to which that help is directed are the subjects of ongoing debate (Caldwell 1982; Kaplan 1994; Lee 1994, 2000; Lee and Kramer 2001). This article adds to this discussion by using time allocation data for a group of Maya subsistence agriculturalists to ask whether children's work helps to underwrite the cost of large families or furthers the economic well-being of the family.

DISTINGUISHING SEXUAL MATURITY AND THE JUVENILE PERIOD FROM JUVENILE DEPENDENCE

The juvenile period is prolonged in humans compared to other closely related species, and provocative debate over the evolution of this life history trait has come to the fore in the recent anthropology, demography, and psychology literature. Explanations for the selective pressures that condition this feature of our life history have been discussed from two broad points of view. One perspective holds that the prolonged human juvenile period is the predicted outcome of the effects that extended human longevity and reproductive life span have on delaying the timing of sexual maturity (Blurton Jones and Marlowe 2002; Hawkes et al. 1998; O'Connell et al. 1999). From the alternate point of view, the long human juvenile period is not explicitly determined by age at sexual maturity but has coevolved with other life history features in response to a shift in feeding ecology to one of calorie-rich, but difficult-to-procure, resources (Hill and Kaplan 1999; Kaplan et al. 2000). (For detailed discussions on these two points of view see Bock 2002; Blurton Jones and Marlowe 2002; Bliege Bird and Bird 2002.)

In much of this discussion, juvenility is defined as the period between weaning and sexual maturity or first reproduction. Age at sexual maturity and age at first reproduction are crucial to discussions of optimality in terms of the time and resources allocated to growth and development versus reproduction, and to the evolution and timing of these life history events. Other research questions (children's prolonged dependence on others; the role of grandmothers and others in supporting juveniles; the relationship between the cost of children, ecology, and family size) revolve around the relative economic contributions of children and adults. Sexual maturity and the juvenile period are related in important ways, but for questions concerning the economics of juvenility we need to distinguish between sexual maturity and juvenile dependence, which do not necessarily covary in humans. In both modern wage labor and some preindustrial populations, children may continue to rely on their parents after they reach sexual maturity, marry, and even have children of their own (Kaplan 1996). Yet in other preindustrial populations, children may be self-supporting at a relatively young age, and the timing of sexual maturity and juvenile independence may be coterminous. What is notable is that the period of time that human children are dependent on others for economic support is variable, and juvenile independence, sexual maturity, and age at first birth may occur at different age intervals.

Three objectives are developed here. First, the duration of juvenile dependence is established for a group of modern Maya subsistence agriculturalists. While there is considerable research on children's economic contributions, we have little empirical data for the *net value* (their production minus their consumption) of children in subsistence economies. The development of Maya children from net consumers to net producers is tracked using time allocation data. The achievement of positive net production is then used as an empirical proxy to define the close of juvenile dependence. Second, the duration of juvenile dependence among the Maya is compared with the durations for several groups of hunter-gatherers and horticulturalists for whom we have similar data. Third, since parents can spend their children's production surplus in a number of competing ways—surpluses can be converted into goods and resources or transferred to help raise younger children—the benefit of children's work to Maya parents is evaluated.

The Maya provide a provocative counterpoint to previously studied groups of hunter-gatherers and horticulturalists for studying juvenile dependence. Depending on cultural context, parents, grandparents, other related adults, productive-aged children, or the government may help subsidize dependents. The role of grandmothers and other extended kin in distributing the cost of children has been well documented among some groups of hunter-gatherers and horticulturalists (Cain 1982; Davis 1955;

Draper and Harpending 1987; Hames 1988; Hawkes et al. 1998; Turke 1988, 1989, among others). However, limited options are available to Maya parents to help support juveniles. In this community of Maya farmers the economic unit of production and consumption is the nuclear family, and help is not systematically transferred across households. Because of family demographic composition, parents become grandparents while they still have a number of dependents living at home and are not likely to play a substantial role in supporting their daughters' juveniles (Kramer in press). Further, villagers have no access to financial institutions for either saving or borrowing money to support their families, nor are government subsidies available to them. On the other hand, the Maya maize economy is supported by many tasks in which coresident children regularly, productively, and safely participate from an early age. Since Maya parents have large families, averaging seven or eight children, and limited help options, the Maya provide an ideal case for studying the role of children's work in underwriting the cost of large families.

THE YUCATEC MAYA

The data presented here were collected in a small, remote village in the Puuc region in the interior of the Yucatan peninsula, Mexico. The 316 residents of the village of Xculoc are subsistence farmers who participate minimally in wage labor and the cash economy. At the time of this study, all families lived in traditional wattle-and-daub, dirt-floor houses and subsisted on maize cultivation. The low-canopy tropical forest that surrounds the village is interspersed with open savannas where the Maya cultivate their maize fields, or *milpas*. Honey is collected from the forest for sale and small quantities of maize may be exchanged in the village stores for limited goods such as vegetable oil, eggs, sodas, and candles. Otherwise, no cash crops are grown. In many households, men may leave the village for short periods of time to engage in wage labor to finance the purchase of a few basic household items, such as cloth, needles and thread, medicine, hammocks, or simple building materials. Women and children are not involved in wage labor or any other income-producing enterprise, and in 25% of the village households men never participated in wage labor.

Basic technologies—a gas-powered well and maize grinder—were installed in the village in the late 1970s, yet participation in the cash economy in terms of education and buying power remain restricted owing to the long distances to market towns. At the time of this study there was no electricity or running water in the village and access to motorized transportation was very limited. There is a rustic primary school in the village where most children learn basic reading and writing skills. However, classes are infrequently held and school rarely interrupts children's work activities. Despite their lack of modern facilities, villagers are well nourished and in general good health.

The household forms the principal economic unit of production and consumption. Each household grows its own food and furnishes the labor to provision the household. Maya children live and work in their parents' households until they marry and begin families of their own in their late teens and early twenties. Marriages are stable and monogamous, lasting until a partner's death. A child is usually born within the first year of marriage. Parents do not have access to modern contraception and family size is large, with a mean completed fertility between seven and eight children (Kramer 1998; Kramer and McMillan 1999).

VARIATION IN JUVENILE DEPENDENCE

How long juveniles are dependent on their parents for support varies considerably not only among humans but also across animal species. Among many species, juveniles become independent of their parents at weaning, whereas among other animals juvenile dependence ends at sexual maturity. Variation across taxa in age at sexual maturity has been accounted for by differences in adult mortality (Charnov 1993) and is one explanation invoked to explain the long juvenile period in humans. But what conditions the variation in human juvenile dependence if it is distinguishable from age at sexual maturity?

The age patterning of production and consumption and the process of children becoming independent of others' economic support are guided in many ways by patterns of growth and development. Body size, strength, physical maturation, and cognitive development impose certain limits on the kinds of tasks that children are able to accomplish, thereby shaping to some extent the age patterning of children's work. Though there may be some differences in growth trajectories from population to population,[1] cross-cultural variation in children's economic contributions is evident within the constraints set by growth and development.

Studying the role that ecology and subsistence play in conditioning variation in the age patterning of children's work across human populations has a lengthy intellectual precedent (Boserup 1965; Clark and Haswell 1967). Cross-cultural variation in the economic contribution of children has been linked to how people make a living because subsistence, at its simplest, delimits the kinds of tasks that children might perform. For example, the economic contribution of children, and especially young children, among circumpolar hunter-gatherers who subsist predominantly on large game and have complex hunting, housing, storage, and clothing technologies will be very different from the work of children in the Australian Central Desert who subsist largely on grass seeds, fruits, nuts, and small reptiles and have minimal clothing and shelter technologies. Yet the relationship among ecology, subsistence, and children's economic participation is more complex than previously thought. Many authors have noted that lower-latitude hunter-gatherer children may help support themselves at relatively young ages by foraging for easy-to-obtain foods such as fruit (Blurton Jones, Hawkes and O'Connell 1989, 1997; Draper 1976; Draper and Cashdan 1988; Hawkes, O'Connell, and Blurton Jones 1995; Kaplan 1997; Kaplan et al. 2000; Lee 1979). However, children's economic participation also varies considerably within a generalized subsistence regime. A comparison of the !Kung and Hadza, two groups of hunter-gatherers who live on the savannas of sub-Saharan Africa, shows that Hadza children contribute significantly more to their caloric intake than do !Kung children (Blurton Jones 1993; Blurton Jones, Hawkes, and Draper 1994a, 1994b; Blurton Jones, Hawkes, and O'Connell 1989). These studies make the important point that the extent to which children acquire their own food resources is conditioned not only by the productive tasks available to them, but also by the costs and benefits associated with children participating in those tasks. For example, health risks associated with foraging, such as heat stress, lack of water, and the presence of large, predatory animals, have a negative effect on the probability of child survivorship and limit the foraging options of !Kung children compared to Hadza children, whose environment presents far fewer risks to unsupervised children.

The age patterning of children's production reflects the outcome of how children spend their time, which they can broadly spend in one of three competing ways—learning, working or in leisure. Why children work at all and do not opt to spend *all* their time in leisure (at play or at rest) is an interesting problem for which two general types of explanations have been offered. First, children work because they incur a fitness benefit by helping to support their siblings (Turke 1988). And second, since children are at a competitive advantage, it is in their best interests to cooperate with their parents (e.g., the "Rotten Kid Theorem": Becker 1981; Bock 2002).

Modeling the time children spend learning versus working is far from simple. One useful framework for thinking about the costs and benefits associated with broad cross-cultural differences in children's work effort involves how children become adept adults in their ecological niche. Nested in what is traditionally framed as the quality/quantity trade-off is a proximate set of parental trade-offs that concerns the benefit that parents receive from a child's work versus the delayed payoff of investing in a child's learning and skills (Bock 1995; Kaplan 1996). This trade-off has been formalized through the concept of embodied capital (Becker 1981, 1993; Bock 1995, 2002; Kaplan 1994, 1996; Kaplan et al. 1995; Kaplan and Lancaster 2000). Parents invest in a stock of embodied capital that may include food and other resources that contribute to their children's physiological development, maintenance, and health, as well as providing their children with skills, training, access to social status, and alliances. Reflecting variation in the complexity of human subsistence strategies, parental investment varies both in kind and duration. If, for example, competently making a living involves skill-based work, parents benefit from forgoing at least some of the products of their children's work to train or educate them more than parents do in unskilled labor economies. In the modern, postindustrial world where children are educated before they go to work, or in other situations where children are trained a priori, this trade-off is fairly straightforward since time spent learning is not time spent working. But the trade-off becomes much more opaque in situations where training is embedded in work.

If how children learn represents a continuum distinguished at one end by formalized education and training and at the other by learn-as-you-work, Maya subsistence is at the latter end of that continuum. Maize agriculture provides many farming and domestic tasks that are generally *not* demanding in terms of *either* skill or strength and can be performed proficiently by children without a long period of training and education. The majority of calories in the Maya diet comes from maize, and maize production and processing involve various unskilled, repetitive tasks that require minimal strength. The Maya do not use draft animals, tractors or other mechanized farming technology, obviating the need for developing special skills to participate in most agricultural activities. Children, although perhaps easily distracted when young, spend considerable time harvesting, weeding, and carrying loads of garden produce to the village. The introduction of fertilizers in the past several years has meant that old-growth forest is now less commonly felled, an activity which required considerable skill and strength. This recent shift in agricultural practices no doubt has precipitated a change in the extent to which children can be involved in field work. Domestic chores such as carrying water, feeding animals, running errands, washing, cleaning, and shelling maize provide numerous other productive roles for children. Importantly, there is currently almost no opportunity to work in jobs that require an education, and parents would benefit little from investing in their children's education beyond the primary schooling they receive in the village. The limited amount of training necessary to be successful at maize production coupled with the unavailability of skill-based wage labor result in a *low* payoff to parents to forgo their children's work and formally educate or train their children.

For most tasks Maya children learn as they work. A seven-year-old boy, for example, is able to discern what part of the stalk contains an ear of corn, open the husk, and remove the ear. Even though he is less efficient at harvesting than an adult or older child, if he misses an ear of corn it can just be picked another day. Thus the risk of resource loss is low, and Maya children spend considerable time in this task.[2]

But there are exceptions. A child is not expected to learn by working if the cost of potential resource loss exceeds the benefit of a less-experienced individual participating in the task. Planting, for example, would appear to be a relatively easy task; it involves plunging a sharpened stick in the ground, dropping a few seeds in the hole, covering it, and moving on—a task that a ten-year-old easily has the strength to accomplish. However, planting is obviously critical to maize production and to household survival, and if seeds are improperly planted, the risk of crop loss is high. Although children are physically capable of it, planting is one task that is performed only by adult males. Though formal training is brief, to be successful at the task requires concentration, attention to detail, ability to gauge environmental cues to schedule planting appropriately—all of which are general cognitive skills that accumulate with age. With the exception of planting, however, many field work and maize-processing tasks have a low risk of loss, and children can become competent by working rather than having to be trained a priori.

Regardless of how capable children may be at accomplishing a task, they are not expected to do so if it compromises their survival and safety (Blurton Jones, Hawkes, and Draper 1994a, 1994b; Blurton Jones, Hawkes, and O'Connell 1989; Kaplan 1994). Although the village is surrounded by tropical jungle, the village itself is a safe domain for Maya children. It is meticulously kept clean and cleared of vegetation so that it is free of many tropical pests that can be especially dangerous to young children. Importantly, while young Maya children may participate in seemingly unsupervised work, an aunt, uncle, grandparent, parent, adult sibling, or cousin is always in close proximity if needed in a village in which most inhabitants are related. The forest is a different matter. Though Maya children grow up hearing folklore and cautionary tales about snakes, insects, and bees and know how to avoid many potentially dangerous situations, young children rarely go unaccompanied into the forest or fields.

Thus because of the relative lack of task difficulty and little need for formal training, coupled with the inaccessibility of skill-based jobs, the economic roles available to Maya children represent a counterpoint to those available to children in many other economic settings. The local Maya maize ecology generally appears to favor children's participation in work along each of these sources of variation—task requirements, how children learn, and health risks—and is expected to strongly condition the age patterning of Maya children's work.

BENEFIT OF CHILDREN'S WORK TO PARENTS

Differences in the delayed payoff associated with investing in a child's training and/or in the survival risks associated with children's work may help to explain why parents *forgo* the products of their children's work in some situations but not in others. But we know less empirically about the *benefit* that parents actually receive from their children's productivity. The extensive literature on children's work has contributed substantially to our cross-cultural appreciation of children's economic roles. Yet the ends to which that child labor is directed are debated. A common view is that children's positive net production is transferred to parents to improve the economic status of the family (studies in the tradition of Caldwell 1982). Though the observation that high fertility is economically beneficial to the family in preindustrial populations is frequently mentioned, recent quantitative research questions this finding (Kaplan 1994; Kramer and Boone 2002; Lee 1994, 2000; Lee and Kramer 2001; Mueller 1976; Turke 1988). This paper looks at this assumption and asks whether Maya parents benefit from their children's work by helping to underwrite the cost of younger siblings rather than fund family wealth per se.

THE MAYA SAMPLE

Reproductive histories were collected from all 316 village members during household interviews by asking residents to list the names, ages, and birth and death dates of their parents, siblings, and children. The 19 households that participated in the time allocation sample were selected to represent the cross section of family age composition. Standard instantaneous scan sampling techniques (Altmann 1974; Borgerhoff Mulder and Caro 1985; Hames 1992; Hawkes et al. 1987) were used to collect a large number of time allocation observations relatively quickly; in this case, more than 20,000 observations were collected over a ten-month field season. An observation period lasted three to four hours, during which the participant's activity was recorded every 15 minutes. The observation day was limited by daylight hours from seven in the morning to six at night. Every effort was made to ensure that all individuals, all times of the day, all days of the week and seasons of the year were equally sampled, and a mean of 154 observations per person was recorded (Kramer 1998), giving an accurate estimate and detailed profile of the proportion of time that an individual spends in domestic, field, and leisure activities (Dunbar 1976). Once bachelor and childless households are excluded, the subset used in the following analysis consists of 112 individuals ages zero to 65, of which 62 are children—defined as offspring living in their natal household and having no children of their own—ages 3 to 23.

ESTIMATING THE CLOSE OF JUVENILE DEPENDENCE

Many studies among agriculturalists have found that children work hard (Cain 1977; Minge-Kalman 1978; Munroe, Munroe, and Shimmin 1984; Nag, White and Peet 1978; Odell 1986; Reynolds 1991; Sipas 1980; Vlassoff 1979; White 1973, 1975; Whiting and Whiting 1975, among others), and the Maya are no exception. By the age of six to eight, Maya children participate in a variety of domestic and field activities (Table 1). The increase in the time spent working then sharply rises at about age 10 and reaches a plateau, approaching adult levels of work in the mid to late teens (Figure 1). Though by their teens Maya children spend as much time working as their parents, it is the age at *positive net production*—when a child produces more than he or she consumes—that marks the close of economic dependence.

Two concerns guided my choice of methods to estimate positive net production among Maya children. First, in order to analyze variation in juvenile dependence I planned to compare my results with Kaplan's information on production and consumption from hunter-gatherer groups (Kaplan 1994, 1996, 1997) and I worked with Kaplan to follow his methods. Second, to establish an age at positive net production, production and consumption have to be tracked in a common currency across the life course. Although it is methodologically more straightforward to use calo-

Table 1. Mean Proportion of Time and Number of Hours That Male and Female Children Allocate to Various Activities in an Eleven-Hour Observation Day

	Proportion of Time Allocated to Work					
	Male			*Female*		
	3–8	9–14	15–20	3–8	9–14	15–20
Domestic Work	3% 0.3 hr	10% 1.1 hr	9% 1.0 hr	10% 1.1 hr	34% 3.7 hr	53% 5.8 hr
Field Work	3% 0.3 hr	14% 1.5 hr	16% 1.8 hr	2% 0.2 hr	5% 0.6 hr	10% 1.1 hr
Wage Labor	—	—	24% 2.6 hr	—	—	—
Hunting and Beekeeping	<1%	<1%	<1%	—	—	—
Nonsubsistence Labor[†]	—	—	4% 0.4 hr	—	—	—
Child Care	<1%	5% 0.6 hr	<1%	7% 0.8 hr	12% 1.3 hr	3% 0.3 hr
Total Work[‡]	6% 0.7 hr	25% 2.8 hr	54% 5.9 hr	12% 1.3 hr	39% 4.3 hr	63% 6.9 hr

[†] Obligatory community labor, travel to a job and community wage labor.
[‡] Does not include child care.

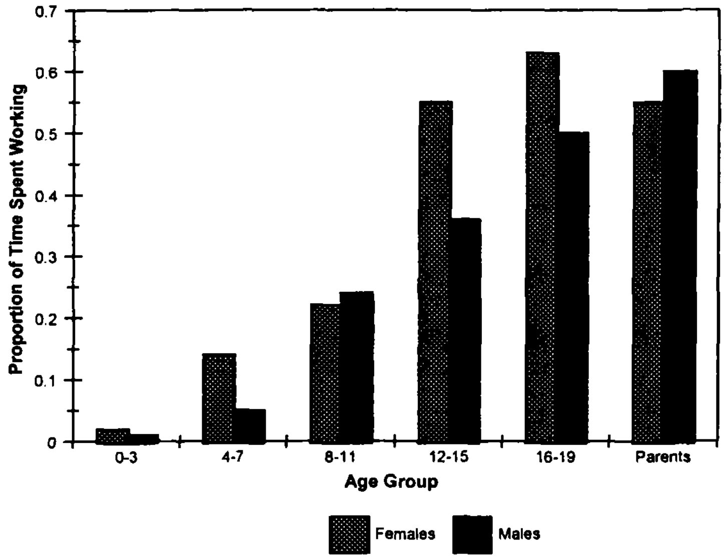

Figure 1. Proportion of time that children and parents allocate to work in an 11-hour observation day.

ries or money as the common currency for how much an individual produces and consumes, neither is appropriate in the case of subsistence agriculturalists for a number of reasons. First, the Maya only minimally participate in wage labor and the cash economy. While wage labor does have a monetary value, men are only very intermittently employed, and women and children never engage in wage labor. Consequently, measuring monetary earnings and expenditures would capture very little of an individual's production or consumption. Second, although a person's daily energy consumption can be reasonably estimated in calories using age, sex, weight, and activity data—variables known for all individuals in the sample—equating production to caloric output is problematic since it would under-represent how much an individual works in the Maya case. Agriculture requires sustained work effort throughout the year and involves activities such as planting, weeding, and maintaining crops, which do not have a readily measurable caloric output. Other processing tasks, such as hauling water, collecting firewood, and many food-related and domestic activities also have no measurable caloric output. Nor do these subsistence tasks have a monetary equivalent since crops, water, and firewood are not sold for profit. Given these considerations, time is the most suitable currency to track production and consumption across the life course.

Time is measured in daily hours of work.[3] Work includes field work (ground preparation, planting, weeding, harvesting, transporting agricultural goods), domestic work (washing, cleaning, sewing, food preparation, running errands, hauling water, chopping firewood, tending animals), and wage labor. Note that although child care was recorded, it is not included in the tally of work for a number of reasons. While direct child care (activities such as washing, feeding, bathing, and nursing) can be clearly observed and recorded, many indirect forms of child care (carrying a child, talking to a child) may not be recorded depending on observer discretion and what suite of activities he or she classifies as child care. Some mothers, for example, are naturally gregarious and talk to their children constantly. Should this be counted as child care, education, or no work activity at all? In some households babies and young children are put in a hammock (used in much the same way as a crib) more often than in other households where young children are instead constantly held or carried. For some research questions it would be critical to consider the time allocated to child care. But for the purposes of this research, child care is not included as work because of the marked effect personal parenting preferences would have on overall work effort. Nonetheless child care is an important activity, especially in young girls' lives. Maya girls allocate 7% of their time to child care compared to the 1% boys spend. If child care were included as work it would considerably boost the time girls spend working, but would have little effect on boys' work effort.

Since simply counting the hours that adults and children spend working does not adequately represent the work effort of individuals of different ages, the average daily hours that an individual spends working is adjusted for the relative value of their time (e.g., Becker 1981). If, for example, a child spends five hours a day rocking her baby brother in a hammock and her mother spends four hours a day chopping wood, is it reasonable to conclude that the child works more than the mother? Counting hour for hour that each spends in these very different tasks does not really reflect the value of their work effort, and it is appropriate to adjust time expenditures to account for differences in the relative value of time. That said, assessing the relative value of agricultural and domestic tasks is an understudied area in time allocation research, and there is no conventional measure of relative value in the sense that wages are used in market economy studies and foraging returns are used in hunter-gatherer studies. Here I have used efficiency and energy expenditure. If other techniques to assess the relative value of time are developed, some adjustment in the methods used here may be in order.

The first value of time adjustment accounts for differences in the efficiency (return rates) of children's work compared to that of adults. Return rates were collected for a number of domestic and field activities[4] and are used to derive an age-specific and sex-specific discount coefficient by dividing the mean age-specific child return rate by the mean adult return rate. The discount coefficients, for example, for harvesting maize, a relatively easy task, are 0.47 for males under the age of 11, 0.71 for males 11 to 13, 0.95 for males 14 to 19, and 1.0 for males 19 and older. The time that a child allocates to harvesting is then multiplied by the appropriate age and sex coefficient, which, in effect, deflates the actual time that a child spends working so that in the data base an hour a child spends harvesting is comparable to an hour spent by an adult. Since return rates were not collected for activities such as cooking, running errands, and carrying maize to the mill, children's time expenditures are not discounted for these tasks and are counted hour for hour.

To further compensate for differences in the value of time and the energetically different kinds of tasks that children and adults tend to perform, an individual's production is adjusted such that the time spent in more strenuous tasks (calorically more expensive) is weighted more heavily than time spent in less strenuous tasks. The scale for weighting tasks is taken from standard coefficients for task-specific energy expenditures data (Astrand 1971; Durnin and Passmore 1967; Montgomery and Johnson 1977; National Academy of Sciences 1989; Ulijaszek 1995).

An individual's consumption is estimated from the *share* of household work that he or she consumes. The share is *proportional* to the individual's daily energy requirements based on age, sex, weight, and activity level—variables collected for all individuals in the sample. The energy requirement for the household is summed across its individual members. Dividing an individual's energy requirement by the household's gives the individual's share. An individual's consumption can then be computed by multiplying the individual's share by the average daily amount of time that the household spends working (production summed across the household). For example, if a household of five spends an average of 22.0 hours a day in work and if a twelve-year-old boy's share is 20%, he is estimated to "consume" 4.4 hours daily of household work ($22 \times .2 = 4.4$). While I could not directly observe how a household's total production is parsed among family members (for example, how much of the time that a mother spends washing clothes does a 10-year-old actually consume?) and used the *share* to estimate an individual's consumption of these types of activities, this method is preferable to basing individual consumption solely on calorie needs or on cash expenditures. In an agricultural economy, caloric consumption or cash expenditures do not account for an individual's consumption of the time that a household spends in crop maintenance, food preparation, water collection, fuel collection, and the many processing tasks important to subsistence. The method used here calculates an individual's consumption as including a broad range of field and domestic activities in which a household engages to sustain its members.

To make these calculations, the mathematical assumption has to be made at some scale that consumption and production are in balance. This assumption can be made at the individual, household, village, or national level. In this case it was appropriate to make the assumption at the level of the household since the Maya live in nuclear family households that typically produce what they consume and consume what they produce. In other agricultural systems, demand for field labor may peak at certain times of the year to harvest cash crops for the market or fell new forest, and assistance from outside the household may be needed. The Maya of Xculoc, however, do not cash crop, nor do they harvest their crops at one time (they store maize on the stalk), and preparing and planting fields occur over a several-month period; rarely does someone from outside the household help in either field or domestic work. What cash may be gained through wage labor endeavors is largely directed back to the family to purchase basic household necessities—cooking oil, candles, medicine. The Maya do not bank resources beyond subsistence needs, and they live in self-supporting households.[5] The implications of this assumption are that an individual household member may be a net producer or consumer, and how much a household produces or consumes may change over the family life cycle, adjusting to changes in demographic pressure, but the household, as a whole, is not a net producer or consumer.

RESULTS

The Age at Positive Net Production for Maya Children

A spline smooth is fit to the individual production and consumption values.[6] Production and consumption can be tracked across childhood, and the age at which children begin to produce more than they consume is used as a proxy for the close of juvenile dependence. The age at which children achieve positive net productivity is shown where the two functions intersect (Figure 2). Maya children increase their contribution to household labor throughout their childhood. Although their level of consumption also increases, their work effort increases more rapidly and begins to approach their level of consumption during adolescence. Females reach positive net production in early adolescence, by the age of 12, when they work about 4.5 hours during an 11-hour observation day. Males reach positive net production a few years later, by age 17, when they also work about 4.5 hours a day. Older adults retain high work loads, maintaining a positive production balance throughout their lives. Although males lag behind females in the time they spend working when they are younger, as adults, both males and females work about 6.5 hours a day.

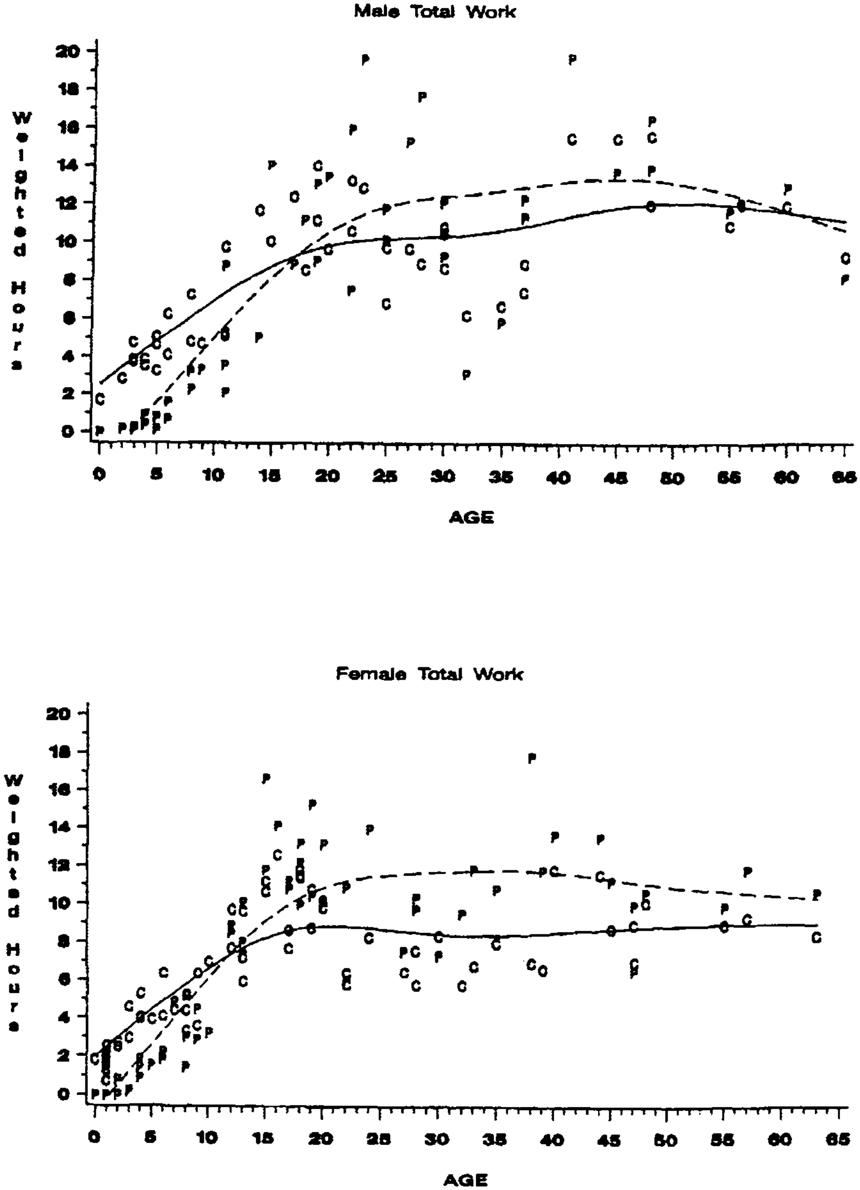

Figure 2. Production (dotted line) and consumption (solid line) across the life course. Production and consumption measured in weighted daily hours of work. P = individual production values and C = individual consumption values.

Age at Positive Net Production: Comparing Hunter-Gatherers and Agriculturalists

The age patterning of Maya children's work and the age at positive net production contrasts markedly with at least several groups of hunter-gatherers for whom we have similar production and consumption data. Kaplan (1994) studied the relationship between production and consumption among three groups of South American foragers and horticulturalists and found that among the Machiguenga, Piro, and Ache, children provide only 20% to 25% of their own caloric needs before the age of 18. Children do not produce more than they consume until early adulthood—ages 20, 21, and 21, respectively—when they already had children of their own. In these foraging groups children remain net consumers throughout their entire period of growth and development.[7] In contrast, among the Maya, juvenile economic dependence ends and positive net production is achieved well before males and females leave home and begin families of their own. Females achieve positive net production at age 12, the mean age at marriage is 19 (n = 50; range 15–29), and the average age at first birth is 20 among the Maya women in this population. Males become net producers at age 17, also prior to the average age of marriage, which is age 22 for males (n = 43; range 16–33). Although the growth trajectories of the Maya, Piro, Machiguenga, and Ache children likely vary to some extent, I suspect that this variation does not have a strong effect in explaining differences in the age patterning of children's work.

Although the close of juvenile dependence differs substantially between groups, the age at first birth is roughly similar. Drawing from a sample of hunter-gatherers, Kaplan and colleagues (2000) found that females tend to be between ages 18 and 20 when they have their first child, which is comparable to the age at first birth among Maya women. Thus from the limited data currently available it appears that juvenile independence and first birth occur in close sequence among some groups, while a lapse of a number of years between these two events is evident in the case of the Maya. The point is *not* that hunter-gatherers, horticulturalists, and agriculturalists are essentially different in the timing of these life history intervals, but that the juncture at which juvenile independence occurs in relationship to when children begin families of their own is variable across human populations.

Although a number of studies in both the economic and anthropological literature have focused on the economic value of children in agricultural societies, they are not directly comparable to the Maya data on the question of juvenile dependence. Many of these studies find that children in subsistence agricultural economies work hard and contribute substantially to household production (Munroe et al. 1983, 1984; Nag et al. 1978; Vlassoff 1979 ; White 1975, among others), yet few report children's consumption. Those that do evaluate the net economic benefit of children, tend to be among intensive agriculturalists who cash crop and are much more reliant on wage labor and the cash economy than the Maya described here. Results are conflicting. Cain's (1977) classic study combines both wage and nonwage labor as production and finds that children become net producers at a young age. Other studies only include wages earned by children as productive work, which under-represents many of the productive tasks in which especially young children participate. Not surprisingly, where children's production and consumption are expressed as monetary earnings and expenditures, results show that children are a net cost to parents (Mueller 1976; Skoufias 1994; Stecklov 1999). Further, many of these studies use interview and census estimates for production and consumption, or present only aggregate, not age-specific, estimates of children's production. A few studies are based on scan samples and time allocation data (Johnson 1975; Minge-Kalman 1978; Reynolds 1991), but consumption data is not reported, or not in the same units of measure as production. Thus a comparison of juvenile dependence based on the achievement of positive net production across agriculturalists would be tenuous at best since methods vary widely.

Benefits of Maya Children's Work to Parents

If, as in the Maya case, children live in their natal households for several years as net producers before they leave home and begin families of their own, what benefit do these older children confer to their parents? Even though Maya children become net producers in their teens, their parents generally have several dependent children also living at home. In this village, for example, all Maya mothers 40 and younger have at least two children under the age of 10; 90% have three or more children under the age of 10; and 50% have four or more children under the age of 10. One observation that can be made about these large families with multiple dependent young is that they are costly in terms of the amount of work that is required to support them. Taken from the time allocation data, Figure 3 shows the number of daily hours of work that a household expends. A family of four, for example, works an average of 20 hours in a day, while a family of eight works about 40 hours per day. Although work effort generally increases with household size, it does not monotonically increase because of the effect of an economy of scale on household production and because of differences in age composition among families of the same size. Smaller families may contain *either* young children *or* teenage children, while larger families, which show a stepped increase in median cost, are composed of *both* younger children who do not produce very much and older children who consume a lot.

Large Maya families are expensive, and at the same time parents have

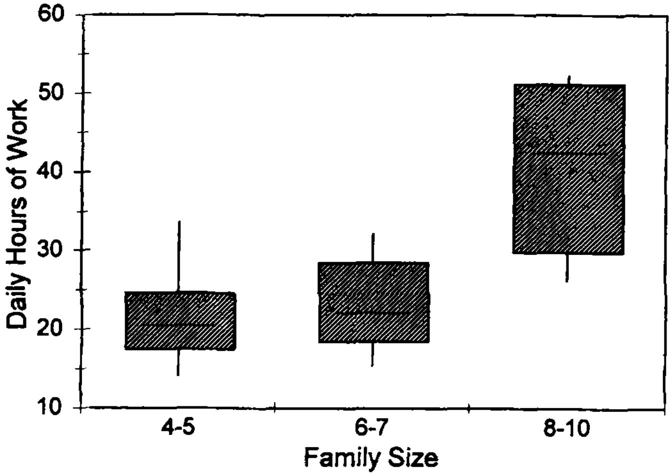

Figure 3. Estimated daily average cost to support Maya families. Cost measured as average number of hours daily spent working summed across family members.

finite time and resource budgets out of which various competing expenditures must be funded—taking care of themselves and their older children, and providing child care for their younger children. The sum of their children's consumption needs cannot exceed the available time and resource budget without parents having to seek help from others. The same graphs used to estimate children's age at positive net production (Figure 2) can also be used to estimate Maya parents' production balance—or the margin of difference between how much parents produce and how much they consume. This balance gives the amount of time that parents have left over to support their family. Although parents have an average production balance of almost three hours a day, this only partially compensates for their children's needs. The amount of labor needed to support the family above and beyond what parents can finance is computed by subtracting parent's production balance from total household consumption (Figure 4). For each household, the residual family need is positive. Regardless of family size, in each case, parents' work effort alone does not meet their family's labor needs.

When we consider household production across the life cycle of the family, children as a group produce more than half of what they consume after the tenth year of their parents' marriage, when the mother is in her prime reproductive years. Children, as a group, produce virtually all of what they consume after the twenty-second year of their parents' marriage, in-

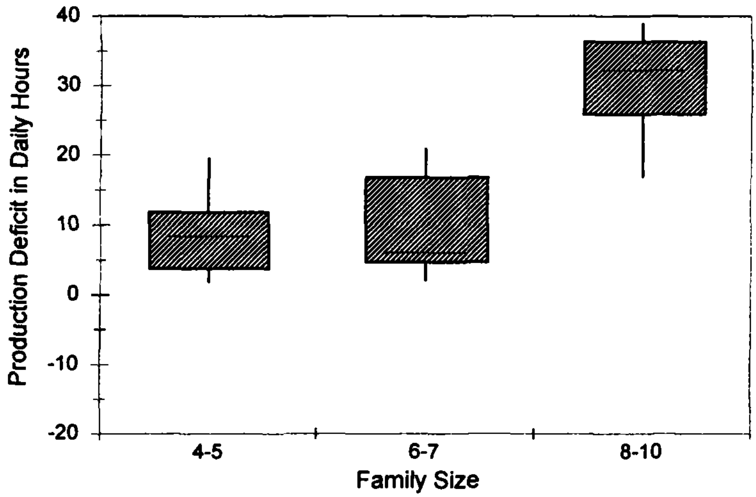

Figure 4. Residual family labor deficit estimated as total household consumption minus the production balance of mothers and fathers.

dicating that the economic contributions of Maya children clearly offset a substantial portion of their consumption (Lee and Kramer 2001).

Three points can be made from these findings. First, older children maintain a positive production balance for a number of years before leaving home. Second, by their mid-teens children spend a substantial amount of time working. And third, parents' production balance is not sufficient to sustain large Maya families and parents must seek assistance from others. When dependency ratios rise and parents reach bottlenecks in their ability to support their dependents, help from children is one option available to them. Maya parents appear to benefit from their older children remaining in their natal households as net producers and helping to subsidize the costs of younger, dependent siblings for a number of years before leaving and starting families of their own.

FUTURE RESEARCH DIRECTIONS

Since Maya children become net producers in their teens, the question of why they do not leave home and initiate reproduction at a younger age is an interesting one. Why Maya teenagers continue to direct their work effort toward their parent's household and siblings, rather than leave home and invest in their own reproductive career once they are economically "independent," may have several explanations that pose future research questions. First, children's production is embedded in household production, and the young age at positive net production may reflect an economy of scale to some extent. If more people working together lowers the per-unit cost of production, young teenagers may not be able to make it on their own and pay the increased per-unit cost of production required to establish their own household. Second, in terms of parent-offspring conflict, there may be some reluctance on the part of parents to forgo the work of their older children, especially if they help to underwrite the cost of younger siblings and subsidize the parent's continued reproduction. But children may also benefit from remaining in their natal households for a few years as net producers and may themselves be hesitant to go. Girls are not yet fully grown, nor have they reached sexual maturity when they become net producers,[8] and most likely they have much to gain by staying at home a few more years. When work is disaggregated task by task, it is apparent that girls, while net producers for many tasks, are still net consumers for some tasks, and thus may not be able to support a household on their own.

Given Maya socioecology and the costs and benefits of children's work previously discussed, Maya parents appear to be in a position of requesting a fair amount of work from their children. But, children also assess the benefits of their labor. Though parents may have in mind an optimal amount of help that they want from their children, their children may have a different appraisal of the level of help they want to give. Most parents experience these conflicts daily. The resolution of this conflict of interest, or the actual amount of work that a child does and for how long, should then reflect some compromise between the parent's and child's conception of the optimal work load. How far the observed value is actually in the direction of either the parent's or children's optimum is unknown, and is an area of study that has not been theoretically developed. However, it seems reasonable to expect that the more work benefits *both* parents and children, the less parent-offspring conflict will arise and the less reluctance there will be on the part of a child to meet parental demands for his or her work, especially as children approach reproductive age.

As children reach reproductive age, the more opportunity there is for children to earn wages, bank their production surplus for the future, or convert their production surplus into nonfood commodities, the less willing children may be to transfer their production balance to their younger siblings. Although the Maya are only marginally involved in wage labor and the cash economy, there are differences between males and females. Most young, unmarried men leave the village intermittently to earn a wage-labor income. These earnings can be given directly to the young man's natal family or converted into building materials or other nonfood commodities so that he can marry and establish a household of his own. Given this opportunity, a young man may be more reluctant to turn over his earnings to his parents and siblings. Maya females, on the other hand, do not participate in any income-producing enterprises, and there may be little conflict in their staying at home a few more years and helping to support younger siblings.

And lastly, Maya children may not be compromising their reproductive success by staying in their parents' households for a few years after they become net producers. Even though Maya children wait until their late teens or early 20s to leave home and marry, they nonetheless raise seven to eight children themselves, which approaches the upper limit of total fertility rates (Bentley et al. 1993; Sellen and Mace 1997).

CONCLUSION

Within the bounds set by gains in body size, there is a great deal of flexibility in the duration of human juvenile dependence. Using the achievement of positive net production as an empirical proxy for juvenile independence, Maya children produce more than they consume in their mid to late teens. This contrasts with the age of positive net production for three groups of hunter-gatherers and horticulturalists for whom we have similar data. Although Maya parents appear to be in the position of requesting a fair amount of work from their children, they are not able to support their dependent children on their own. The production surplus of older coresident children appears to help underwrite the cost of younger dependent children and enables parents to continue reproduction when they might otherwise not have enough time and resources to do so.

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NOTES

1. Though this area of study is yet to be explored, for the purposes of this paper I am assuming that the growth trajectory of Maya children does not appreciably vary from that of Ache, Piro, and Machiguenga children such as to determine the difference in age at positive net production.
2. Female children age 8 and older spend between 1% and 3% of their time harvesting maize; mothers spend 2%. Male children age 8 and older spend between 3% and 6% of their time harvesting maize, and fathers spend 6%.
3. The average number of daily hours is calculated as the proportion of total scan observations that an individual spends in work divided by the total number of observations for that individual and multiplied by an 11-hour observation day.
4. Chopping wood, collecting water, harvesting maize, planting maize, weeding, shelling maize, and making tortillas.
5. Although I did not observe systematic interhousehold labor transfers, in the event that a particular household is a net consumer and depends on economic or labor transfers from nonmembers, then the production of its members will be overrepresented.
6. The age at positive net production, where the production line crosses the consumption line, is affected to some extent by different smoothing procedures in S+ and SAS. Generally methods with a higher resolution (for example, narrower spans in the loess procedure) retain more detail and produce wavier lines. The values plotted are conservative in the sense that they come from a relatively wide span and low resolution, and therefore avoid the risk of overfitting the data. Across *all* the methods, the age at positive net production remains 12 for females but varies from 17 to 19 for males. The stability in girls' age at positive net production compared to boys' reflects the greater variability at any one age and across ages in male work effort. Regardless of smoothing procedure, the positive net production threshold is always prior to the average age at marriage.
7. The age at positive net production for the Piro, Machiguenga, and Ache would probably be pushed down to some extent if a greater range of domestic tasks were included as work, as they were for the Maya.
8. While the age for the onset of menses is unknown for Xculoc women, a mean age of 13.3 has been reported for Yucatan Maya women (Yewoubdar 1989). This sample of women is from a rural village of 2,500, which is much larger than Xculoc and close to an urban area and market center. Sabharwal, Morales, and Méndez (1966) report 14.5 and Eveleth and Tanner (1976) 15.1 for age at menarche among rural Guatemalan Maya women. Eveleth and Tanner's estimate is from the recalculated probits using Sabharwal and colleagues' data.

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