

Children's Help and the Pace of Reproduction: Cooperative Breeding in Humans

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Because children's ability to support themselves falls below their consumption, human young are subsidized by others throughout much of their growth and development. Mothers, however, who often have multiple dependents of different ages, are faced with an allocation problem (Fig. 1). This has led to important debate about the evolution of a long period dependence and the development of nonmaternal strategies to provision young. This article focuses on the critical role that children themselves play. Because the human subsistence niche incorporates a broad diversity of resources that require variable procurement and processing costs, dependent children can also be important producers, furthering both a need and an opportunity for cooperative breeding.

One conspicuous life-history feature of primates generally and humans specifically is the lengthy period after weaning when young continue to grow and develop. Humans take more or less twenty years to reach reproductive maturity and begin to produce children of their own, almost twice as long as other closely related primates of similar size (Fig. 2). For children, the transition to economic independence is a protracted though cross-culturally variable process. For mothers, the long duration of offspring dependence coupled with rel-

atively short birth intervals and a high probability of child survival means that mothers in natural-fertility populations are often in the position of simultaneously raising multiple dependents of different ages. These attributes of human life history—a rapid reproductive rate, mothers having dependents of various ages, and expansion of dependency through the juvenile period—contribute to the prevalence of cooperative breeding to raise young across human populations.

Among nonhuman primates, carrying and grooming may continue situationally during the transition from weaning to full independence.^{1–3} Mothers may assist juveniles, let them forage in close proximity, confer protection and agonistic support, and help negotiate social position. But before a subsequent birth, nonhuman primate young are well on their way to, if not accomplished at, food-provisioning. Human weanlings, however, depend on someone else for growth and survival often up to and even long after sexual maturity.^{4,5}

Children's growth and development can be stratified into four general stages: infancy, childhood (young children), juvenility and sexual maturity. Childhood is defined by slow body growth rates between weaning

and the eruption of permanent molars and completed brain growth, which occurs by about the age of seven in modern populations.⁶ Because brain growth is calorically demanding, yet teeth and digestive tracts are immature, children require calorie-rich but easily digestible and low-volume food. In its broadest definition as a general life stage shared by other mammals, juvenility is defined as the duration between weaning and sexual maturity, often marked by the age of first birth. As human juveniles develop, they make the transition to eating adult food, which, depending on habitat, some of which they may procure. However, they are often subsidized by others not only during childhood but also throughout the juvenile period.

Since mothers often have multiple dependents and because infants, young children, and juveniles benefit from different kinds of investments, mothers are posed with an allocation problem: how to provide high-quality child care without sacrificing economic activities that feed younger and older children.^{7–13} Reflecting this, seminal debates in anthropology have centered on alternative strategies to provision young. These debates have focused, for example, on the importance of grandmothers^{14–17} and male parental investment.^{18–21} This paper adds to this growing discussion by examining those features of human children and subsistence ecology that further a demand and an opportunity for cooperative breeding.

Cooperative breeding, a reproductive strategy and social system in which nonparental members of a social group help to support offspring who are not their own, is relatively rare, but occurs across diverse taxa, predominantly

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Key words: children's economic value; reproductive strategies; human juvenility; maternal tradeoffs; natural fertility populations; human life history; human subsistence ecology; Maya



Figure 1. Pumé mother balancing her role as child-care and food provider (Photo: Greaves, 2002).

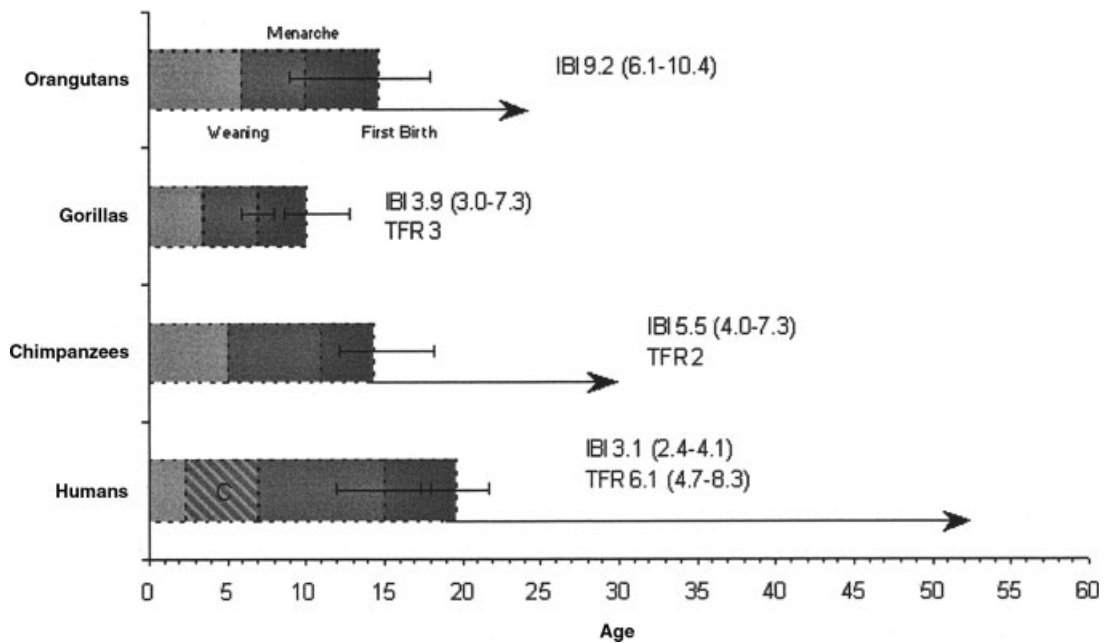


Figure 2. Comparative life-history variables for select primates showing age at weaning, age at menarche, age at first reproduction, and average life expectancy given survival to reproductive age. Bars show ranges for age at menarche and age at first birth. Sources: Orangutans: age at weaning⁶⁶; age at first birth, birth intervals, life expectancy at age 15.¹¹⁸ Gorillas: age at weaning¹¹⁹; age at menarche (Watts, 1991),¹³⁵ age at first birth, birth intervals¹²⁰; Total Fertility Rate (TFR).⁷² Chimpanzees: age at weaning¹²¹; age at menarche¹²²; age at first birth, birth intervals¹²³; TFR, life expectancy at age 15.⁷² Humans: age at weaning,⁷² age at menarche¹²⁴; age at first birth (mean for Ache, !Kung, Hiwi, and Hadza)⁷²; life expectancy at age 15,⁷² TFR (mean for 57 groups of foragers, horticulturalists and agriculturalists)¹²⁵; birth interval mean (mean for Ache, !Kung, Amele and Turkana)¹⁴; range: lower (Kramer, 2002);⁵¹ upper.¹²⁶

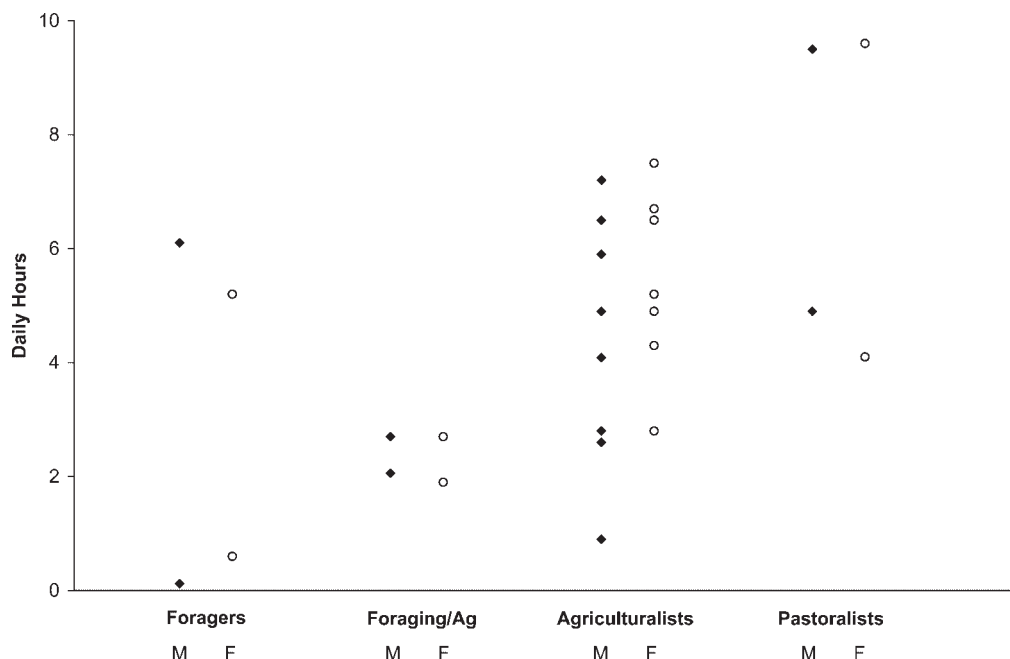


Figure 3. Children at work. Daily hours that children cross-culturally spend in productive activities. Sample limited to natural-fertility subsistence populations (a minor portion of calories coming from wage labor). Values reported are daily hours children allocate to foraging, hunting, field work, and domestic tasks taken from published sources (where child care is included as domestic work, it is noted below). Sources: Foragers (bottom to top): !Kung, 4–14-year-olds⁵⁰; Hadza, 6–13-year-olds.¹⁶ Forager/Agriculturalists (bottom to top): Mikea children, weaning to adolescence (includes child care¹²⁷); Machiguenga, 6–13-year-olds¹²⁸; Agriculturalists: Switzerland, age group not specified¹²⁹; India, Skoufias, 14–17-year-olds¹³⁰; Maya, 9–14-year-olds⁵¹; Java, 9–11-year-olds⁵⁴; Java, 10–12-year-olds⁵⁵; Mayo, age group not specified,¹³¹ Nepal, 9–11-year-olds⁸⁴; Bangladesh, 10–12-year-olds (child care included in domestic work).²⁹ Pastoralists: Ariaal, 6–11-year-olds.¹³²

birds, wild canids, mongooses, rodents, and several species of primates.^{1,22–27} Help benefits mothers by redistributing the cost of raising offspring, which may have a positive effect on reducing birth intervals, raising maternal fertility or infant survival. Although the role of children in subsidizing siblings has been well documented in the fields of economics, demography, and anthropology,^{10,28–35} several considerations are important to place humans in the framework of cooperative breeding.

This article reviews those concerns with a specific focus on the relevance of extended offspring dependence to cooperative breeding. An overview of the available time-allocation data for children illustrates the kinds of assistance that children provide. Because juveniles in many traditional societies are both consumers and producers, attention is given to the analytic challenges this presents in determining the effect of their contributions on reproductive success. Cross-cultural comparisons are limited to natural fertility populations, not only because natural fertility was the human evolu-

tionary reproductive milieu but because family planning and economic options to raise children, which affect the need for and cost of help, are very different in market-economy populations where contraception is practiced. Foragers, agriculturalists, and pastoralists are included in the survey of natural-fertility populations since both the level of fertility³⁶ and the level of children's economic contributions cross-cut these classifications (Fig. 3). The methodological issues raised here are applicable across modes of production. The last section considers the implications of children's contributions as allomothers to two key features of the human adaptation—demographic proliferation and geographic expansion.

CONSTRAINTS ON REPRODUCTIVE RATE: BALANCING MATERNAL ALLOCATIONS TO CHILD CARE AND FOOD PRODUCTION

Among nonhuman primates, allo-maternal care is associated with accel-

erated infant growth and shorter birth intervals. Help with carrying infants, for example, allows mother to forage more efficiently and reallocate energy from carrying, an energetically demanding activity, toward lactation and the production of young.^{37–41} Among humans, however, mothers may benefit more from help that resolves the competing demands of caring for younger and older children than they do from help that decreases their investment in infant care *per se*. Among the Toba of Argentina, for example, helpers did not have a significant effect on the time mothers spent nursing or in other child care activities. However, nursing women who lived with female helpers spent less time in domestic work.⁴² In his seminal time-allocation study among the Ifaluk, Turke³⁵ showed that girls contribute substantially to the subsistence economy and that mothers who bore girls early in their reproductive careers had greater completed fertility than did those whose first-born children were boys (but see Hames and Draper⁴³).

TABLE 1. MEAN PROPORTION OF DIRECT CHILD CARE RECEIVED BY AN INFANT FROM VARIOUS CARETAKERS

	Mothers	Fathers	Siblings	Grandmothers	Other Related/Unrelated
Ye'kwana	49%	2.7%	♀ 16.7% ♂ 1.9%	11.2%	20.6%
Agta	51.7%	4.4%	♀ 10.2% ♂ 1.1%	7.6%	—
Maya	46.1%	1.6%	♀ 31.6% ♂ 4.6%	1.2%	11.2% ^b 2.8%
Alyawara ^a	53%	<1%	31%	—	16%
Toba	50%	—	♀ 33% ♂ 4%	12.5%	—
Efe ^c	50%	6%	♀ 13% ♂ 14%	9%	9%

^a Values reported for carrying children only. Values for male and female children reported as an aggregate.

^b Aunts comprise 8.4% of other related childcare.

^c Values from focal follow data.

Sources: Ye'kwana¹¹⁴; Agta¹¹⁵; Maya⁸⁷; Alyawara¹¹⁶; Toba¹¹⁷; Efe (Ivey Henry, unpublished data).

Any mother has a finite time and resource budget out of which various competing expenditures are funded: taking care of herself, caring for infants, providing specialized food for younger children and adult food for older children. She therefore makes decisions about how to allocate her time. The time mothers allocate to child care shows surprising cross-cultural similarity (Table 1). This regularity may, in part, reflect that no one can substitute maternal time spent nursing, and that mothers can downwardly adjust time allocated to child care only so much, regardless of the availability of helpers. However, mothers may readjust time spent in activities that support older children.

Among the Ye'kwana, neotropical agriculturalists, time-allocation data show that mothers are challenged to care for infants while simultaneously maintaining a normal amount of garden work. When Ye'kwana mothers have very young dependent children, they spend less time in economic activities, but do not compromise the time allocated to child care.⁷ Among the Hiwi and Ache, South American horticulturalists and foragers, nursing mothers decrease their foraging effort relative to nonnursing mothers.^{18,44} Nursing Hadza women, hunter-gatherers living in the woodlands and savannas of northern Tanzania, have lower foraging returns and return rates than do women with older children.⁴⁵ Nursing Maya mothers allocate significantly less time to field

work; nursing mothers with infants less than a year old spend no time in field work.⁴⁶ These studies suggest that mothers with a nursing infant and older children balance the increased demands of a newborn by reducing the time spent in domestic activities, foraging activities, or field work rather than time spent in child care.

A sample of natural-fertility populations for which time allocation data are available shows that children allocate some time to child care (Fig. 4). But regardless of mode of subsistence, children cross-culturally allocate substantially more time to economic activities. While allomaternal child care offsets material time constraints to some extent, it is economically that children make their greatest contribution. These patterns suggest that the rate of human reproduction may be more sensitive to help directed toward economic activities that support children during childhood and juvenility than to help with child care during infancy.

HUMAN SUBSISTENCE FROM A CHILD'S PERSPECTIVE

From the viewpoint of the child, especially a young child trying to make it on his or her own, the human feeding niche is complex. All human diets incorporate a diverse suite of plant, animal, and often aquatic resources. In addition to food procurement, many of the foods incorporated in the

human diet require processing: butchering, cracking, hulling, winnowing, shelling, leaching, pounding, grinding or cooking. Young children are incapable of these processing tasks and juveniles, depending on the particular task, may or may not have the strength or skill to accomplish them.⁴⁷ Besides processing, in many environments dependence on stored food for at least part of the year is critical to solving overwintering or hyperseasonal problems in resource availability and predictable annual resource shortfalls. Storage may require boning, drying, salting, and smoking as well as the use of specialized tools, structures and containers. In most human environments, besides food procurement and processing, survival also minimally entails proficiency at tool manufacture and shelter and clothing technology, activities that may be beyond the grasp of a child's ability. Only under dire circumstances does a child live on his or her own and concomitantly fund all of the tasks necessary for survival.

Low-Cost Juvenile Help

Although human juveniles are economically dependent, they also are a potential source of low-cost help for several reasons. Helping may have energetic costs and trade-offs with health risks, but because juveniles are not yet fully grown, sexually mature, or competing for mating opportunities, they do not compromise their

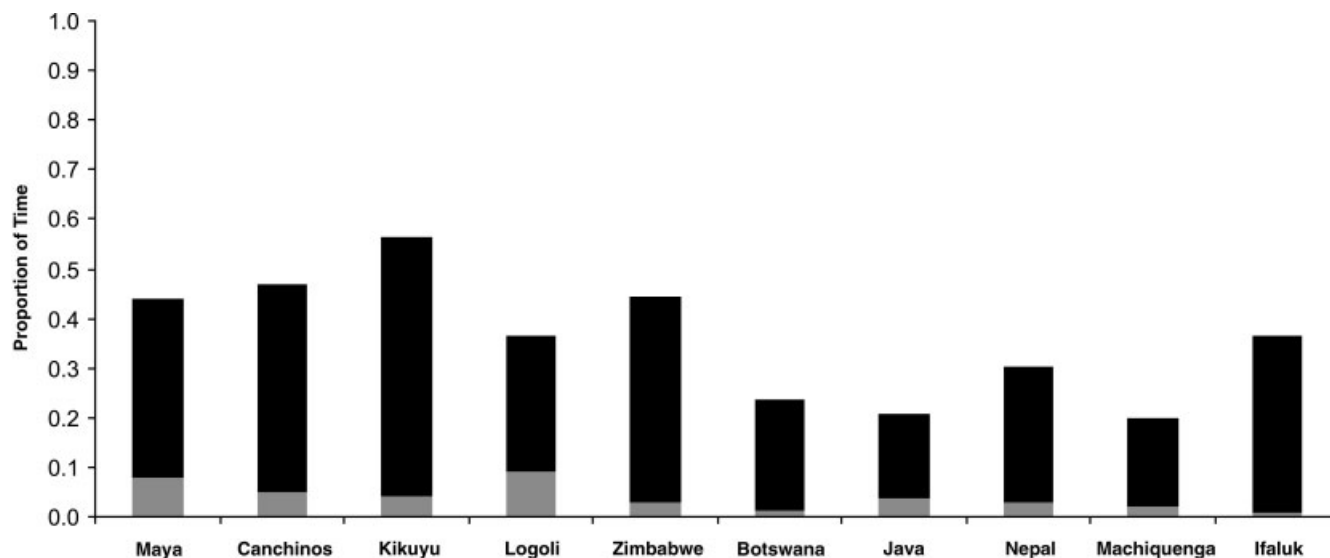


Figure 4. Proportion of time that juveniles allocate cross-culturally to child care (gray portion of bar) and economic work (black portion of bar). Values averaged for males and females. Sources: Maya, 7–15-year-olds⁵¹; Canchicos, 6–10-year-olds¹³¹; Kikuyu, 6–10-year-olds¹³³; Logoli, 6–10-year-olds¹³³; Zimbabwe, 10–18-year-olds³³; Botswana, 7–15-year-olds¹³⁴; Java, 6–14-year-olds⁸⁴; Nepal, 6–14-year-olds⁸⁴; Machiquenga, 6–13-year-olds¹²⁸; Ifaluk, 11–15 year-olds.³⁵

own reproductive success by helping. In addressing the evolutionary puzzle of why helpers help, emphasis has been placed on the indirect fitness benefits to the helper. However, recent research suggests this emphasis may overshadow positive direct benefits. The cost of helping may be low, especially when the benefits to a helper's survival are high.²² This point has clear implications with respect to humans, since juveniles, who fall short of where they need to be to make it on their own, have much to gain by maintaining their dependence. Even though juveniles are sexually immature and closely related to their siblings, the cost for them to help may also be low for another reason.

The human feeding niche has the important feature of incorporating a broad diversity of foods that require variable procurement and processing costs. While juveniles depend on others for some of what they need to survive, they also may be successful at procuring some of the resources they need and, indeed, some in excess of their own consumption needs.

Where children live in safe environments with easy-to-obtain foods, they may spend considerable time foraging for fruit or shellfish, snack foods that are an ideal package size for children and require little processing. Under these circumstances, children may

contribute substantially to their caloric intake.^{20,28,48–50} For example, among the Hadza, children provide 50% of their caloric intake by the age of five.⁴⁹ Among subsistence agriculturalists, Maya boys by the age of seven and girls by the age of six produce 50% of what they consume.⁵¹

Within any one subsistence regime, children's economic dependence also importantly varies across resources and tasks. Among foragers in the Western Desert of Australia, for instance, children can successfully capture small game, such as reptiles and rodents, and collect grubs and fruit, but depend on others for seed cakes and larger game.⁵² In other food production activities children may produce enough to meet their own needs as well as the needs of their siblings. In another forager example, a Pumé boy living on the llanos of Venezuela is successful at bringing home a catch of fish, enough fish to feed himself and his siblings. But he also depends on shares of processed plant food and larger game from others.⁵³ Among subsistence agriculturalists, an eleven-year-old Maya boy spends 3% of daylight hours, or about a half an hour a day, harvesting enough maize per day to meet his own consumption needs as well as those of his siblings. However, he does not directly consume the maize he harvests, but does

so after it has been shelled, leached, soaked, ground into meal, and processed as tortillas, tasks that his older sisters and mother perform.⁶³

How much time children spend at a task and how efficient they are at that task has been theoretically linked through opportunity costs, or the foregone benefit to an individual to invest in one activity and not another.^{54,55} One interesting point that comes out of this is that even though children may be less efficient than adults, the opportunity cost for them to participate in certain tasks is low since they can do little else with their time at a higher rate of return. For example, the Maya boy in the earlier example can harvest maize at a return rate of 30 kilos per hour, or 0.61% that of the mean adult male return rate. Nonetheless, he allocates as much time to the task as an adult since few other activities offer a higher rate of return.⁵⁶

In sum, the opportunity cost to juveniles for helping is attenuated since they are not competing for mating opportunities and there are few competing ways to spend their time. Although some procurement, manufacture, and processing activities may be beyond their scope, from the juvenile's point of view human subsistence has the important characteristic of incorporating a broad diversity of re-

Box 1. Do Children Help?

Interest in children's economic lives has been launched from two main theoretic domains, behavioral ecology and economics. Both approaches to the quality-quantity tradeoff emphasize the cost of raising children (parental investment offset by children's contributions).^{77,78-80} The proliferation of empirical studies that followed the theoretic link made between children's labor and fertility⁸¹⁻⁸³ illustrated that the relationship was far from straightforward, in part

because of methodological differences in how children's economic value was defined. For example, studies in both the economic and anthropology literature have found that children spend considerable time in productive field and domestic activities and are an economic benefit to the family. Other studies have found that when consumption is balanced against production (net production) children are a net cost until and even after sexual maturity. Still others have

found that wealth flows (cumulative lifetime consumption up to each age minus cumulative lifetime production up to that age) are such that the net transfer of resources and labor is downward from parent to child well into adulthood. What conditions variation in the relationship between help and reproductive rate remains unclear since each measure answers different questions about children's value as helpers.

Analytic Perspective	Questions Addressed	Studies
Time (Production)	How much time do children spend working? What is the age and sex patterning of children's activities?	82-85
Net production (Production minus consumption)	At what age do juveniles reach independence? What is the age-specific cost (production-consumption) of children?	29,86-89
Wealth flows (Cumulative net production minus cumulative net consumption)	What is the net cost of childbearing? At what age do children pay back their lifetime cumulative cost? Is the net flow of wealth upward from children to parents or downward to children? Are children a net economic asset?	35,86,90-94
Timing across the family life cycle (Age-specific production and consumption across the demographic family life cycle)	What effect does children's production have on parental time? How does the level of consumer demands and parental and child production change with family size? How much do children as a group offset their cost and the cost of siblings? Who subsidizes dependent young and how does that change as the family matures?	62,88,95

sources and tasks to procure and process those resources. They can accomplish some activities at the level of their own consumption and produce a surplus for others. Consequently, in traditional subsistence economies helping is often embedded in the same general suite of activities as self-provisioning. If a Pumé girl, for example, spends several hours processing bitter manioc, some portion of that work contributes to her own well-being and some portion goes toward subsidizing her siblings. This underscores one of the central methodological concerns in situating children in the context of cooperative breeding, how to define help and helpers.

DO CHILDREN HELP?

One question that is central to assessing the adaptive significance of cooperative breeding is whether help-

ers really help? The weight of evidence from animal behavior studies shows that helpers have a positive effect on parental reproductive success.^{25,57-60} However, this remains unclear with respect to humans for several reasons. Help from children is difficult to calibrate and measure and, together with ecological variation in the mode of subsistence, has contributed to prolonged debate over what otherwise might be simple empirical questions: Are children helping? And is the effect of their help on parental time and reproductive budgets positive? Identifying what conditions variation in children's economic contributions and its effect on fertility has been further hampered because of differences in how children's economic value is evaluated (Box 1).

How we think about help and helpers depends in part on whether the question is approached from the eth-

nographic present or from evolutionary past. From the point of view of the modern mother, since juveniles are subsidized any contribution a child makes offsets his or her cost and the amount of subsidy that a mother or someone else has to make. From the point of view of a mother in the evolutionary past, when juveniles in all likelihood were autonomous feeders, help would have been assistance beyond self-provisioning. In other words, is a helper an economically independent individual? If so, in the modern human case does that exclude young children and juveniles as helpers? Or, given that the human subsistence niche is such that juveniles and even young children may not be independent but are nonetheless significant producers at some tasks, such as harvesting, fishing, collecting shellfish, foraging for fruit, and hauling

water, should helpers be more broadly defined?

Time allocation data collected during a year-long study with a group of Maya subsistence agriculturalists (Box 2) is used as an example to evaluate both of these vantage points in terms of children's economic contributions alleviating parental time constraints. Rather than delimiting helpers based on age or developmental status, helpers can define themselves using the age- and sex-specific relationship between an individual's level of production and consumption.

As children grow and develop, they consume more, but also produce more (Fig. 5). Infants are fully dependent on others, but children increasingly contribute to their own consumption. From the age of seven until fifteen years, Maya boys produce more than half of what they consume. The transition from net consumer to net producer occurs during their sixteenth year, marking the close of dependency. Maya females, not shown in Figure 5, have a similar transition, but become net producers a year earlier, by the age of fifteen years.

Figure 6 shows variation in the age of economic independence for the few natural-fertility populations for which both production and consumption data are reported in the same currency. While Piro, Machiguenga, and Ache children provide 20% to 25% of their own calorie needs by the age of eighteen years, Maya eighteen-year-olds have been surplus producers for several years. Reflecting this difference in the timing of the transition to net production, Piro and Machiguenga older adults work much harder than do Maya adults.⁶¹

Positive net production empirically marks the duration of offspring independence and is a clear indication that these teenagers, who live in their natal home several years more, not only are paying for themselves but are generating a production surplus. Juveniles, though not net producers, produce much of what they consume. Importantly, if total work is disaggregated, juveniles are net producers when they perform easier tasks such as harvesting and water collection, but are not engaged in other tasks such as planting maize and food prep-

aration.⁵⁶ Thus, a Maya juvenile may harvest enough maize to feed himself and his family, but consumes shares of his father's hunting returns, emphasizing that juveniles, while not independent, may offset their own cost and also provide help beyond self-provisioning through some tasks.

DOES CHILDREN'S HELP AFFECT PARENTAL TIME OR REPRODUCTIVE RATE?

Parents are in the position of balancing all of their dependents' consumption demands and the competing demands on their time to support both younger and older children. To assess whether constraints on parents' time are offset by their children's contributions, children's helping behavior is viewed from the perspective of shifts in labor supply across the life

How we think about help and helpers depends in part on whether the question is approached from the ethnographic present or from evolutionary past.

cycle of the family.

Many demographic changes occur across the life cycle of the family. Marriage unions form and sometime later a child is born. First-born children become productive workers while their mothers are in their prime childbearing years. Children born later are still young when their older siblings marry, leave their natal households, and begin families of their own. Parents age and become grandparents while they have several dependent children living at home. As children enter and leave the family through births and marriages, not only does the number of children fluctuate, but so does the ratio of young children, who consume little and produce even less, to older children, who consume more but also produce more.

Maya reproductive histories can be used to construct a heuristic framework to track demographic pressure across the family life cycle as a family matures and consumer demands and labor supply shift. In the first step, demographic changes across the family life cycle are constructed using the average age at marriage, which is 21.6 years for Maya males and 18.7 years for females; the average birth interval at each parity, which is about two years; and the average completed family size, which is 7.2 people. A life table appropriate to a village's level of mortality is then superimposed to calculate the age distribution of surviving household members. To model children's economic value from the viewpoint of a parent, average age- and sex-specific levels of production and consumption derived from the time-allocation data are folded into these demographic changes so that consumption demand relative to labor supply can be observed across the life cycle of the family. These methods are fully explained in Lee and Kramer⁶² and Kramer.⁶³

Figure 7 shows a mother's and father's production (time spent in domestic work, field work, and wage labor for those males who participate; see Box 2) relative to their family's total consumption from the onset of marriage to the birth of the first child, the birth of the last child, and the departure of the first and last child. The deficit in parental production relative to family consumption increases during early parities, but is greatest after the last child is born, when most children are living at home.

The relative economic contributions (time spent in domestic work, field work, and wage labor) of mothers, fathers, and children of different developmental status across the family life cycle are shown in Figure 8. Parents are responsible for virtually all of their family's production during the first five years of marriage. Children's contributions play a substantial role during the peak demographic squeeze during the mid-portion of the family life cycle when parents have seven to eight

Box 2. Maya Study Population and Data

The Xculoc Maya are subsistence maize farmers who live in a village with a population of 316 in the interior of the Yucatan Peninsula, Mexico. The majority of calories they consume come from maize, though the Maya also cultivate beans, squash, sweet potatoes, peanuts, and other fruits and vegetables. Honey is collected for sale and small quantities of maize may be exchanged in the village store for limited commodities such as vegetable oil, eggs, and candles. Otherwise, no cash crops are grown. At the time of this study there was no running water or electricity in the village. Villagers participated minimally in wage labor and the cash economy. Although a rustic primary school had been built in the village, classes were held infrequently and schooling had little impact on children's labor. Maya children live and work in their parents' household until they are in their late teens or early twenties, when they marry and begin families of their own. Endogamy is common, and after marriage, most couples stay in the village and establish fields of their own. Mothers and fathers spend equal amounts of time supporting their family, with both allocating 6.5 hours daily to productive activities other than child care during their prime reproductive years.

Time allocation data were collected during a year-long study using scan sampling and focal follow techniques.^{96–98} Each participant was scan-sampled every other week throughout the field season for an observation period of three to four hours. During an observation period, an indi-

vidual's activity was recorded every 15 minutes. The following analyses include 112 individuals ages 0 to 65 years and draw on over 17,000 scan observations. These are used to compile a detailed profile of the proportion of time an individual spends in agricultural activities (ground preparation, planting, weeding, harvesting, and transporting field goods); domestic tasks (washing, cleaning, food processing, food preparation, cooking, chopping firewood, hauling water, and tending animals), and wage labor.

For work effort to be comparable across age and sex classes, two adjustments are made to convert the simple proportion of time an individual spends working into an estimate of individual production. For example, if a mother and her twelve-year-old daughter chop wood for an hour they are likely to return to the village with very different quantities of wood. For their work effort to be comparable, the first adjustment accounts for the relative efficiency (return rates) of children compared to adults and of males compared to females. The second adjustment accounts for differences in the value of time.⁷⁷ Because some tasks require greater caloric expenditure, more strenuous tasks are weighted more heavily than are less energetically costly tasks.^{99,100}

An individual's consumption is converted into the daily hours he/she consumes of agricultural activities, domestic tasks and wage labor. Consumption is expressed in hours and is proportional to an individual's daily caloric requirements and household size.

Maya children consume about 3.3 million calories from birth to age 20. Although food is one of the most important resources, measuring production or consumption based on calories alone underestimates both children's dependence on and contribution to a wide variety of domestic and field activities that do not have a caloric (or monetary) output. For example, some portion of the time that a juvenile spends each day hauling water provides water that is consumed by her siblings. Some portion of the time a mother spends each day processing food provides food consumed by the juvenile. Among the Maya, 80% of time spent working is related to food production: processing, preparation, hauling water, collecting firewood—activities that are necessary for survival and that women and children primarily fund. Expressing production and consumption as time has the advantage of expanding their definition beyond food and including this range of other tasks.

In the graphs that follow, production and consumption are expressed in weighted hours as explained earlier. Weighted hours are on an order of magnitude greater than real-time hours as follows: for individual males age 0–6 years, 1.00–1.5; ages 7–15 years, 1.3–1.8; >15 years, 1.5–2.3; for individual females ages 0–6 years, 1.0–1.5; ages 7–15 years, 1.2–1.8; and >15 years, 1.5–2.1. For an overview of the study site and methods, see Kramer.^{51,87,95}

children living at home and are least able to support their dependent young.

The inverse of parental share of household production indicates by what factor parents would have to increase their production if children made no economic contribution. If children produced nothing, Maya parents would have to work 2.5 times as hard as they do to maintain their children's consumption be-

tween the 20th and 33rd years of the family life cycle. Were it not for the economic contributions of children, parents in their fourth and fifth decades would have to increase their work effort by 150%, each parent working more than 16.5 hours a day (real-time hours). Parents could not possibly sustain this level of production. Children as a group offset a substantial portion of their own consumption, producing 80% of what they consume in the 20th year

of the family life cycle and virtually all of what they consume by the 28th year, when Maya parents still have several children living at home.^{62,63} Across the demographic life cycle of the family, Maya children play an important economic and reproductive role by enabling parents to continue childbearing during life-cycle stages when parents themselves may not have sufficient time and resources to support their family.

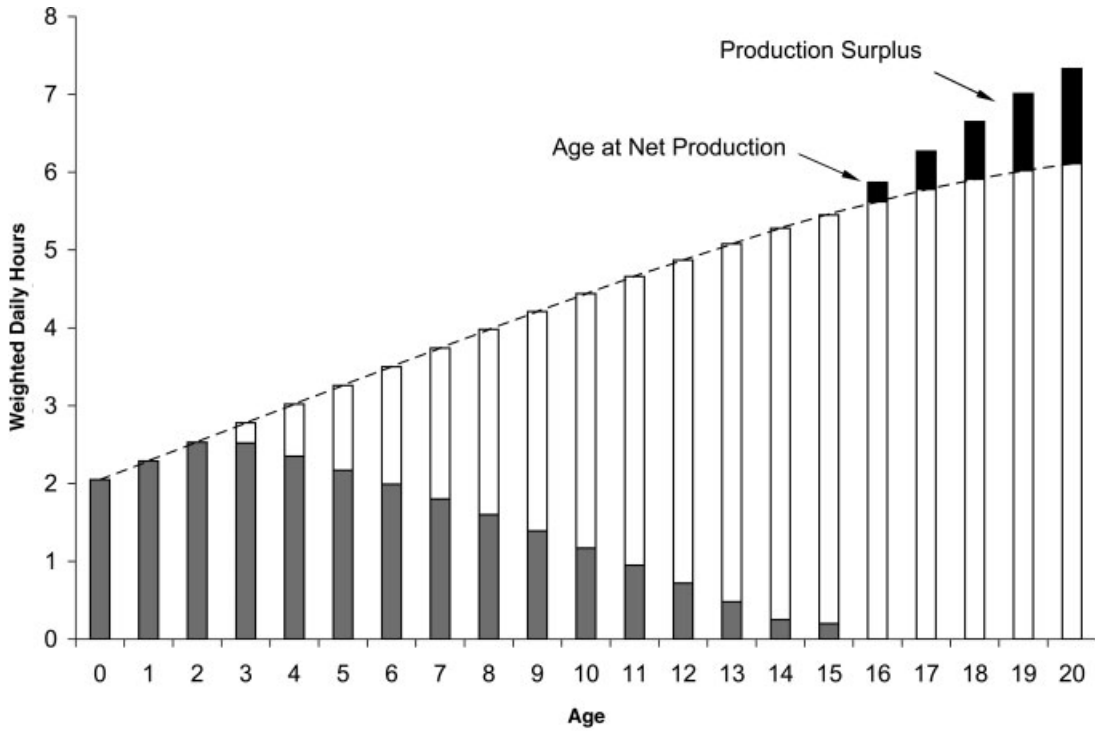


Figure 5. The age-specific relationship of production to consumption from birth to the age of twenty years for an average Maya male child (see Box 1). The dotted line shows total consumption at each age. Bars show the portion of consumption not met by production (gray) and the portion offset by production (white). Black portion of bar denotes production in excess of consumption.

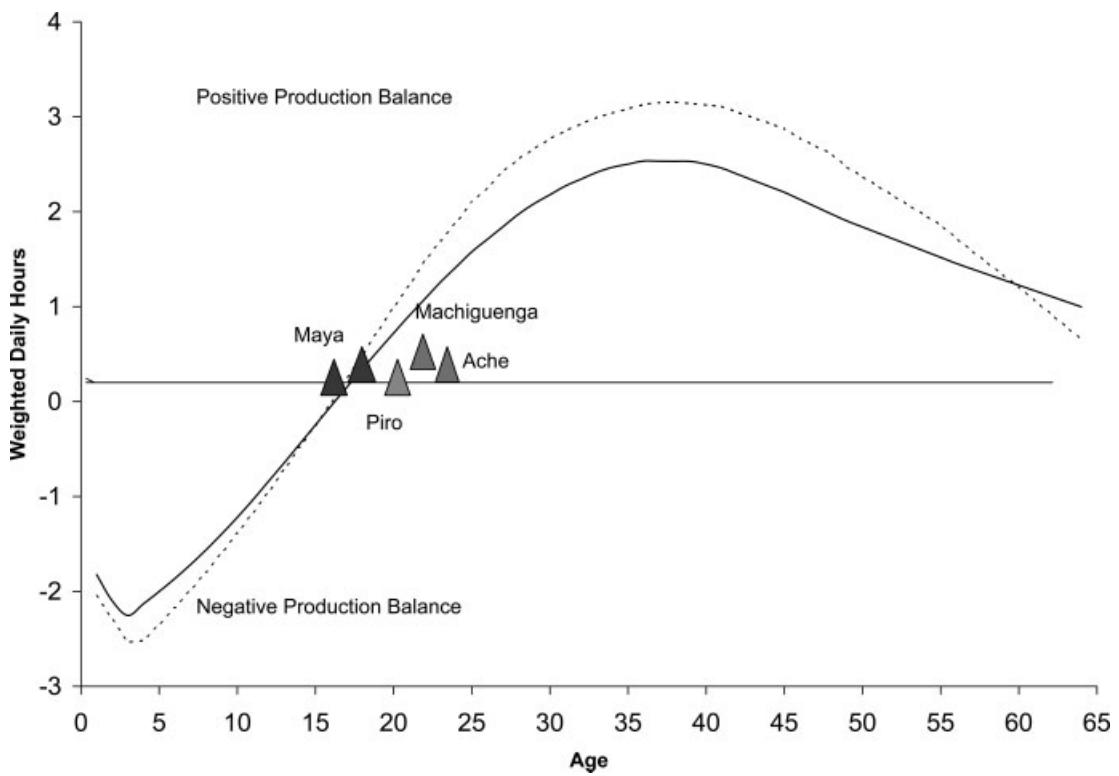


Figure 6. Age-specific production minus consumption for Maya females (dotted line) and males (solid line). Markers denote the age at which production equals consumption for the Maya⁵¹ and three South American populations.⁸⁶

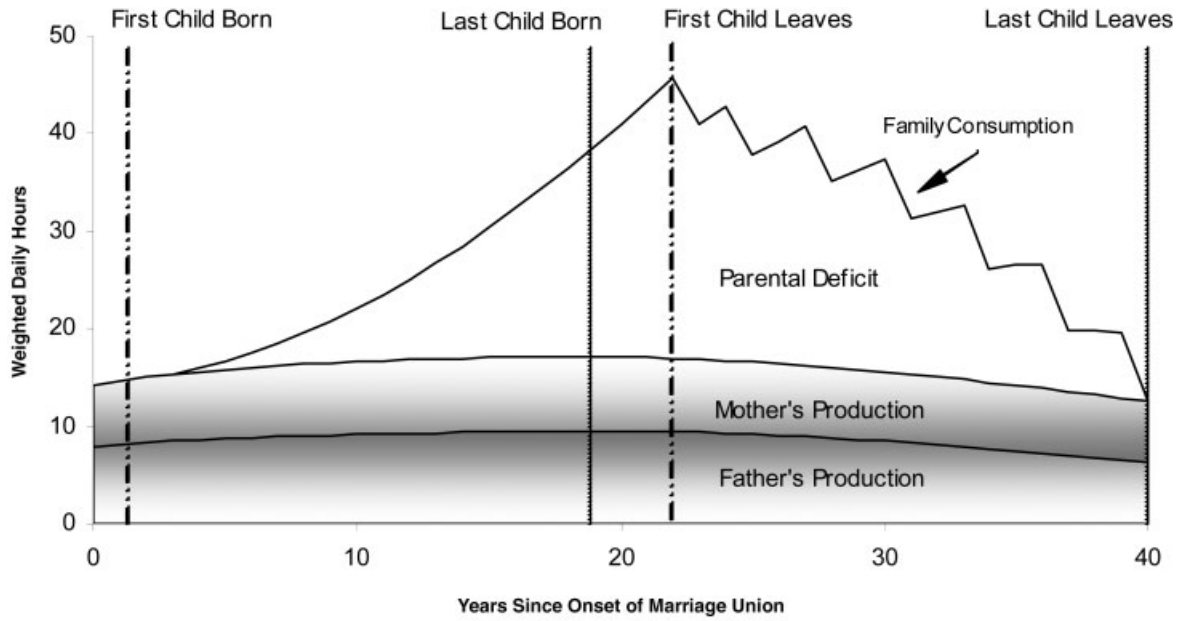


Figure 7. Maya mothers' and fathers' production relative to family consumption across the family life cycle. Family consumption is the sum of consumption across family members. Parental deficit is the family consumption minus the mother's and father's production.

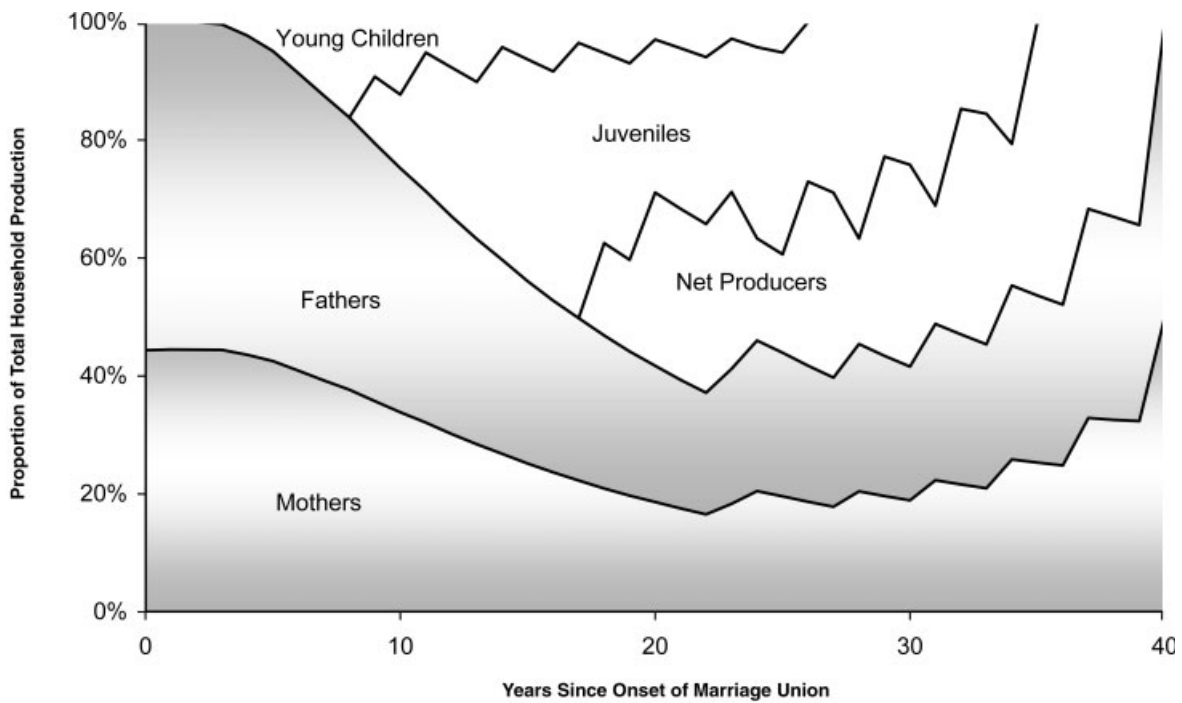


Figure 8. Time that Maya mothers, fathers, young children (0–7 years), juveniles (8–16 years) and older coresidential children (17–21 years) allocate to production across the family life cycle. Time is expressed as proportion of total household production.

DEMOGRAPHIC ADVANTAGE OF THE DISTRIBUTION OF OFFSPRING DEPENDENCY

One potential advantage of the distribution of children's dependency and productivity over several developmental stages is its implications with regard to the demographic and geographic proliferation of humans. While hominid evolution is traditionally explained as long-term directional selection to constant environmental trends, Potts⁶⁴ pointed out that the idea of an environment of evolutionary adaptiveness is inconsistent with what is now known about local and global dynamics in the environmental past. Rather than digging in adaptively to fill a particular niche, an alternate means of coping with variable environmental conditions is to increase versatility. Concomitant with locomotor, cognitive, and social traits that broaden adaptability is the evolution of a human life-history pattern that is favorable to reproductive success and survival in a range of environmental conditions.

Population growth in long-lived, large mammals is generally limited by generational time. The great ape life history of long birth intervals, extended infancy, and relatively high juvenile mortality places further limits on lifetime reproductive success. The population growth potential of the great apes nears demographic equilibrium.^{65–67} Humans, in contrast, are capable of staggering population growth. Because the duration of key developmental stages varies across primate life histories, constraints on reproductive rate also vary. Great ape mothers manage the demands of slow-growing young through protracted infancy. For human mothers, slow growth and dependency is distributed across infancy, childhood, and juvenility, producing a very different effect on population growth potential.

Although young children are no longer dependent on mother's milk, childhood in many ways is an extension of infancy in that young children, who are unable to procure and process the specialized foods they need, depend on provisioning by others for their survival.^{68,69} If the periods of in-

fancy and childhood are considered together from the point of view of the young's dependence, their duration is comparable to the period of infancy in the great apes (Fig. 2). However, from the point of view of the human mother there is a significant distinction. Once a child is weaned, a mother can physiologically prepare to bear another child and reinvest energy from nursing to pregnancy.^{70,71} The insertion, then expansion, of childhood as a developmental stage and the shift in dependency from breastfeeding to food provisioning allow mothers to produce children in relatively rapid succession.

Yet the potential gain in lifetime fertility from an increased reproductive pace could also be countered by elevated mortality risk because maternal time and resources are spread too thin. The traditional view of past human population growth is that gains in fertility were kept in check by high mortality, with the net effect of low population growth. Nonetheless, population growth was sufficient to produce an estimated world population of one billion before the onset of the modern demographic transition. This magnitude of growth, though diminutive compared to what it would be during the modern transition, is demographically remarkable compared to the constraints on great ape population growth. Differences in primate infant and juvenile mortality rates⁷² suggest that human mothers maintain relatively short birth intervals without increasing child mortality. Redistributing the cost of reproduction appears to be a key to balancing the human life-history combination of a relatively rapid rate of reproduction and a high probability of child survival.

Because human offspring are subsidized during childhood and juvenility, mothers commit to raising multiple young.⁷³ Several lines of evidence suggest that some form of allomaternal assistance had to be in place before mothers consigned to producing long-term dependent offspring, and that the level of dependence and commitment to cooperative breeding increased over time.^{10,74} In all likelihood, the direction of selection was from self-provisioning juveniles to extended dependence. Hrdy⁷⁵ points out

that some degree of allomaternal assistance from immature individuals, postreproductive females, and possibly fathers was already available, and that prolonged offspring dependence came as a corollary of such cooperative breeding.

Provisioning juveniles allowed humans to move into habitats they could not have lived in if juveniles were self-feeders.¹⁷ It is often tacitly assumed that as provisioning extended further into juvenility, self-provisioning decreased in step. In those ecological situations where it did not—where juveniles were able to provision themselves to some extent or had foraging, processing, or procurement returns for some resources in excess of their consumption—the demands of extended dependency may have been further offset through their transfers to other dependents. Dental patterns suggest that the protraction of childhood and the feasibility of the short birth intervals characteristic of modern natural fertility populations occurred fairly recently, following the emergence and geographic dispersal of *Homo erectus*.⁷⁶ The push then toward increasing commitment to allomaternal assistance may have been punctuated both before extended dependence and again with geographic expansion and a further shortening of birth intervals.

Several points are made in summary. First, the most difficult time for mothers to meet their children's consumption is when children are older, not younger, when they require food and other investments rather than child care. Following this, while juveniles assist in child care, they spend far more time in economic activities. Second, the time children allocate to economic tasks is variable, but the differences cross-cut mode of subsistence. This suggests that children's help varies with costs and benefits specific to subsistence ecology and social organization, not with whether a child is a hunter-gatherer, agriculturalist, or pastoralist *per se* (Box 3). Third, from a child's point of view, the human feeding niche has the important characteristic of incorporating a broad diversity of resources that re-

Box 3. Sources of Cross-Cultural Variation in Children's Helping Behavior

The role that ecology and subsistence play in conditioning the age patterning of children's work has a long tradition of study.^{108,109} How people make a living has an obvious link to variation in the economic contribution of children since subsistence, as its simplest, delimits the kinds of tasks

children can perform. However, empirical studies show that children's economic participation expresses a range of variation within the general subsistence regime and that mode of production alone—knowing whether a child is a hunter-gatherer or an agriculturist—is not a good predictor

of the level of children's economic contribution. Rather, the extent to which children work is conditioned both by the economic tasks available to them and by the costs and benefits associated with participating in those tasks and the opportunity costs of spending their time in other ways.

Approaches to the Costs and Benefits of Helping	
Learning and maternal experience	10,103,104
Indirect fitness benefits	35,94
Rotten-kid theorem	47,77
Task skill and strength requirements; tasks available to children; resource opportunities	47,48,105-108
Opportunity cost to train or educate children	47,79,109-111
How children learn	87
Health risks	86,106,112
Marginal value of alternate sources of help	113

quire variable capture and processing costs. In many ecological situations, while children are subsidized, they are able to produce some of what they need at the level of their own consumption and some of what they need in excess of their own consumption.

The period of dependency for humans, while prolonged compared to that of the great apes, is spread over the developmental stages of infancy, childhood, and juvenility. Because it is not confined to infancy, physiological constraints on reproductive rate are attenuated. But short birth intervals present other trade-offs and an allocation problem for mothers. Not only is dependency distributed across several life-history stages, but so is the cost of dependency. The Maya data suggest that parents only have enough time to support about four children. In situations where the reproductive rate exceeds this level of fertility, as it does in most natural-fertility populations regardless of mode of production, children's contributions are an alternate or additional means of maintaining the relatively short birth intervals characteristic of modern human reproduction. The relatively fast rate of human reproduction appears to be sensitive not only to children's self-sustaining activities but to direct help to mothers. In addition to their children, mothers may

receive help from their spouses, their own mothers, other female kin, and unrelated individuals. Flexibility in allo-care strategies to alleviate constraints on maternal time and resource budgets under variable ecological and demographic conditions gives rise to a number of pathways to cooperative breeding.

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