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Introduction

There are many important questions, still not fully resolved, about economic activities of individuals in the context of the household life cycle in traditional societies and the direction and magnitude of intergenerational transfers. An understanding of these aspects of the economic and demographic life cycle in traditional societies is of interest for a variety of reasons. One is fertility theory, with the well-known assertion by Caldwell (1986) that in traditional societies, parents desire a maximal number of children because in these societies wealth flows upwards across age, on net, from children to parents. Cain (1977) began the empirical exploration of these ideas with an influential paper on the economic value of children in a village in Bangladesh, based on a time use study. Kaplan (1996) argued from an evolutionary point of view that like other animals, people have evolved to achieve reproductive fitness by investing in their children, not the reverse. He showed that in three traditional groups, including two analyzed in the present paper, children were heavy net consumers, and even elderly adults were net producers. A second set of issues surrounds the ways in which families or households respond to demographic pressures on consumption over the family life cycle, as initially explored by Chayanov (192/1965). A third set of issues concerns the way in which transfer patterns change across socio-economic systems, including foragers (hunter-gatherers), horticulturalists, agriculturalists, and industrial societies. Lee (2000) suggests that for the first three systems, transfers are always downwards on net, although a retirement stage clearly emerges in many agricultural societies, while transfers appear to flow upwards, on net, in modern industrial societies. A fourth set of issues surrounds the age patterns of investment in human capital, that is learning to produce, and the later life returns to these investments. We will only touch on this topic here. Finally, Lee (2002) argues that the evolution of the age pattern of human mortality was driven by the age pattern of cumulative net transfers in forager groups.

We will address some of these topics through demographic and statistical analysis of detailed data gathered in field work by two of the authors. Data for a Maya horticulturalist group come from earlier field work by Karen Kramer in the Yucatan, and data on two forager-horticulturalist groups come from Hillard Kaplan’s fieldwork with the Piro and Machiguenga in Peru. The data are used to construct individual measures of production and consumption. All three groups are quite isolated from markets and from government influence. In all three groups, possibilities for storing output or accumulating capital goods are very limited or nonexistent, so that transfers of output among individuals are the main or only means for smoothing consumption over the life cycle. While transfers are not observed directly, age patterns of net transfers can be inferred as described later in this paper.

A comparative analysis of several groups is useful for a number of reasons. First, each of these groups has a relatively small number of individuals, so there is considerable
uncertainty due to sample size (if we think of sampling over time, or from similar
groups), and uncertainty is reduced if patterns in different groups are similar in basic
respects. Second, the food sharing arrangements differ across the sites. Among the Maya,
food is shared within households. While there is symbolic sharing across households, in
practice each household's budget must be in balance each period. Among the Piro and
Machiguenga, households are joined in kin-based clusters, and food is shared at this
higher level of aggregation. There are multiple clusters within each group. Third, the
methods and measures differ across these field work sites. While the studies of the groups
in Peru focused on acquisition of food calories through hunting and gathering, through
agricultural activity, and to a small extent through wage labor (for the Piro), the Maya
study took a broader view of productive activity, and included many household tasks
associated with preparing food and so on. The Maya study was time-based, while the Piro
and Machiguenga studies were based on caloric output.

After briefly describing the field study populations and sites, we will discuss our
statistical methods. We will then compare and discuss the smoothed age profiles of
production and consumption for the three groups. From these, we will calculate various
individual measures related to transfers, such as the cumulative net transfer profile and
the cumulative economic breakeven age; the internal rate of return to children viewed as
investments; and the average ages of production and consumption in the population, and
thus the net direction of transfers. A second part of the paper will view the consumption
and production of individuals in the context of the households or clusters within which
they share food. Production and consumption will be estimated as functions of age and
sex, with fixed effect multipliers for individual households or clusters. Using these new
age profiles, Chayanov ratios will be calculated at the level of households or clusters. The
degree of demographic smoothing achieved by sharing at the cluster level will then be
assessed. The estimated fixed effects themselves will then be examined in relation to the
Chayanov ratios to assess effects of demographic pressures on consumption and
production.

The Field Study Sites and Populations
The Maya study group lives in Chuloc, a village in the Yucatan peninsula of Mexico.
Field work was done in 1992-93. At that time, the village had very little involvement
with either the market economy or the government, and was a five hour walk or two hour
bicycle ride from the nearest paved road giving access to a market town. The people
practice subsistence short fallow agriculture, with little constraint on land availability.
The primary crop is maize, but fruits and vegetables are grown and small domestic
animals are kept. They also do some hunting. The village has about 200 residents.
(Karen -correct?) The study population is 110 people living in 16 households. On
average, there were seven children ever born to women over 45. There were too few
deaths during the study period to permit measurement of mortality.

The Piro study group lives in Diamante, in southeastern Peru, at the base of the Andes.
Field work was done in 1988-89. They obtain food through horticulture, fishing,
gathering, shotgun hunting, and some wage labor. They sell about 10% of their product
and buy a corresponding share of the food they consume. The community consists of 142
members, 75 men and 67 women, with just over eight children on average ever born to older women.

The Machiguenga study group lives in Yomiwato, in southeastern Peru on a small river. Field work was conducted in 1988-89. At that time, the group had almost no access to money or wage labor, and lived in a protected national park area. They obtained food through bow and arrow hunting, fishing, gathering and swidden horticulture. The group had 88 members, 42 men and 46 women, with just over eight children ever born to older women.

Measurement of Production and Consumption

There is not space to describe the methods for each site in detail. Fuller descriptions of the data collection methods for the Piro and Machiguenga groups can be found in Kaplan (1996) and for the Maya in Lee and Kramer (2001). Food, which is the most important item of consumption, is eaten from a common pot in all groups, precluding its direct measurement for individuals in any of the groups. Consumption is always measured indirectly. First, standard tables are used to compute basal metabolic needs of individuals based on age and body size. For the Maya only, an additional adjustment is made based on the energetic requirements of observed physical activities. Second, the demographic unit within which food sharing takes place is identified. For the Maya, this is the individual household. For the Piro and Machiguenga, this is the extended family cluster of several households sharing a compound. Third, total production as measured for the sharing unit is then assumed to be allocated to individual consumption in proportion to the caloric needs as calculated in the first step. Note that this assumes that all that is produced is consumed in the same period, so that there is no saving of output. This is a reasonable assumption in these contexts.

Production is measured in different ways at the different sites. For the Maya, individuals are observed and their activities are recorded at 15 minute intervals for 3 or 4 hour blocks of time every few weeks throughout the year. On average, there are 155 such observations per individual. Activities include not only field work, but all kinds of work including home production tasks. Some of these activities yield observable outputs, and based on these, the relative productivities of individuals by age and sex can be directly calculated. Activities that require greater energetic expenditure are taken to be correspondingly more highly valued. The comprehensive accounting for all work activities distinguishes the Maya study from the studies of Piro and Machiguenga, which focused on food. This is a strength of the study, but it also creates difficulties for comparative purposes.

For the Piro and Machiguenga, the cluster was the sampling unit, and the sampling frame was one of three four-hour blocks of time during the day. All food brought into the cluster was evaluated for caloric content, and those calories were assigned to the responsible person, with some responsibility shared fractionally. Food eaten away from home was also counted. The calories acquired in this way were divided by the number of days to get caloric production per day. In addition, all large game that was killed was evaluated, and allocated to all hunters in general to avoid extreme sampling uncertainty
since this was a rare event. Finally, similar accounts were kept of the output of poison-fishing events, and the catch allocated to participants. A total caloric production for each individual was based on these three kinds of activities. On average, there were 10 to 15 sample days per individual in the two communities, depending on age and location. In these groups, work that was not directly related to the acquisition of food was not counted, in contrast to the Maya study.

**Methods of Constructing Individual Age Profiles of Consumption and Production by Sex**

Using the methods described, we obtain an estimate of production and consumption for each individual in the sample. In the first part of our analysis, we focus on production and consumption at the individual level. To do this, we construct aggregate age profiles of production and consumption for males and females. This requires that we smooth and average across the individual data points. There is no obvious best way to do this. We have experimented with 1) simple averages for conventional five or ten year age groups; 2) fitted polynomials in age; 3) local regression, specifically loess with spans .35, .50, and .67, the default in S+; and 4) super smoother (supsmu) which selects the optimal span in a local regression through cross-validation, that is by choosing a span to minimize the error variance in a set-aside sample, calculated over all possible set-asides. Through visual inspection for plausibility and assessment of over- versus under-fitting, we selected what we judged to be the best procedure for each group. We have always used the same fitting procedure for all estimation within the same group.

For the Maya and Machiguenga, the male and female populations were just at the border of the recommended sample size (40 observations) for using supsmu. Concentration of the population at the younger ages compounded the low number of observations. In these populations, the results with supsmu showed clear signs of overfitting. We chose loess (.50) for both the Maya and the Machiguenga. The Piro population is somewhat larger, and the supsmu appeared to give the best fit in this case. After fitting the curves, we adjusted the consumption schedules by a multiplicative constant to make the population-weighted sums of consumption and production equal, as they were before smoothing. For some purposes, consumption is subtracted from production at the individual level to obtain net production, and then this is smoothed as described above. At other times, net production is obtained by differencing the smoothed production and consumption profiles.

Figure 1 illustrates the problems of fitting a smoothed line to the data points, and gives a sense of how much difference the choice of smoother can make. It plots the individual data points for Machiguenga male production, along with four fitted smoothed lines: supsmu, and loess with spans of .35, .50, and .67. There are 42 data points, and because the population is young, most of the observations (26) are for children under the age of 20. There are only 16 data points at age 20 and above, and only 7 at 30 and above. There is not a single data point between ages 37 and 56. This is the most sparse of all the data sets analyzed, and it has the largest gap in age coverage. The fitted smoothed lines look quite different one from another. Based on this plot, one would be hard pressed to say which smoother did the best job. Considering all the plots for the Machiguenga
(production, consumption, net production, all for both sexes), we decided that the
loess(.5) performed consistently the best. The observations for consumption are always
more closely clustered around the fitted line than for production, and choice of smoother
often makes little difference in this case. Smoothed net production is intermediate
between production and consumption in the importance of choice of smoother.

For comparative purposes, it is helpful to standardize in some way the age profiles of
consumption and production for the three groups, since Maya data are in hours, while the
Piro and Machiguenga data are in Kilocalories, and there are differing estimates of
consumption per day for the latter two groups. We have standardized the age profiles by
dividing all the production and consumption schedules for a group by the average daily
consumption of males and females from age 0 to 49 (calculated as the sums of the male
and female consumption profiles from ages 0 to 49 divided by 100). The units of
consumption and production cancel out, leaving comparable indices. The standardization
will not solve the problem of differences in method and comprehensiveness of measure,
but it will make it possible to plot the age profiles on a common scale and compare their
shapes.

**Estimated Age Profiles For Production and Consumption**

**Production**

Figure 2 compares the standardized production profiles for females and males. The Maya
stand out for an earlier start to production, and relatively lower production later in life,
for both males and females. The production profiles for Piro and Machiguenga males
look very similar, and show productivity rising strongly with age, to levels much higher
than those of the Maya males. For females the patterns are less consistent, with the
Machiguenga showing a puzzling plateau of low productivity in the 20s and early 30s.

It would be premature to draw any substantive conclusions from these data, because the
methods and concepts underlying the Maya measures are different from those for the
other groups. For the Maya, all time spent in home production is counted in addition to
activities that result directly in food, and it is possible that children's contributions in this
area are important but uncounted in the hunter-gatherer groups. This will also affect the
measured productivity of women in important ways, and might be related to the low
measured productivity of Machiguenga women. Future analysis of the Maya data will
explore this possibility by calculating results based solely on calorie generating activities.

Despite these problems, we offer the following substantive interpretations, with the
understanding that their evidentiary basis may vanish. The short fallow agriculture of the
Maya is relatively simple to practice and does not require much physical strength. On the
one hand, this means that children can be productive while young, and on the other hand,
there is little return to training and experience, so that productivity does not rise much
with age after 20. By contrast, foraging is very skill intensive, and children have low
productivity because they are still learning how to do it. Learning is a life long process,
and productivity rises steeply with age reflecting the return to growing knowledge and
skill.
More specifically, young male foragers are less productive than middle aged men for several reasons. They are still learning how to hunt (and, in the case of the Piro, learning some western occupations, such as driving boats and chainsaw work, as well). They have smaller gardens because they do not have a family to feed. As men age into their 60s, their physical abilities decline, affecting their hunting returns, so they concentrate more on gardens and tool manufacture (high skill, low exertion). Through their gardens, they maintain reasonably high levels of caloric production, some of which is used to support grandchildren. However, their nutritional contribution is declining at a greater rate than the calorie contributions indicate. The Machiguenga believe that children will not grow without sufficient meat (manioc and plantains have virtually no protein or fat), and they spend a great deal of time getting it. Kaplan’s research suggests that garden calories are produced several times more efficiently than hunted calories, and they constitute about 80-85% of the diet. Development of a satisfactory method for assigning relative value to meat and garden produce as well as the output of other activities is a high priority for this research. In the Maya data, relative value is determined by relative time spent in production, taking into account age-sex differences in production for a given task.

Consumption

The consumption profiles in Figure 3 also differ. Both boys and girls among the Piro and Machiguenga consume more than the Maya. There is also a dip in the Maya consumption profile centered on age 30 for both males and females, but this may reflect sampling error combined with the idiosyncrasies of the smoothers, or possibly a reduction in non-child related home production time by mothers. It is important to note that Maya consumption was calculated taking account both of resting metabolic expenditure (REE) by age, sex and weight, and the energetic expenditures on physical activities. Consumption for the other groups was based on REE alone. Kaplan (1994:786) suggests that the REE method “may overestimate the food consumption of children and underestimate consumption by adults”. It is also important to note that consumption for the Maya also includes the imputed value of home production activities, which will reduce the measured net productivity of Maya men relative to women compared to the foraging groups. Once again, further analysis of the Maya data could clarify these points.

Net Production and the Breakeven Age

We now turn to net production, which is simply production minus consumption. The net production of adults is linked to the deficits of children, since by construction the balance of production minus consumption is 0 for the population as a whole. The population age distribution matters as well as the smoothed age profiles in this regard. If the population age distribution is young, with many children per adult, then surplus production for adults will have to be higher. All three groups have similarly young population age distributions, since each has a TFR in the 7 to 8 range (mortality has relatively little effect on population age distributions compared to fertility). A well-known analytic result tells us that in stable populations with aggregate production equal to aggregate consumption, the internal rate of return over the life cycle for the survival weighted net production profiles (averaged for males and females) would equal the population growth rate. With a mean age of childbearing around 30 and a population growth rate around .025, an adult
must generate roughly twice \((e^{30\times0.025}=2.2)\) the surplus needed for the net consumption of a single child.

Because net production is the difference between production and consumption, it will be affected by the measurement issues discussed for each of these earlier. Figure 4 plots net production flows for females and males. The most striking feature is that Maya children's negative net production is only a half or a third as great as that of the other groups. The breakeven age for the girls is at 12 years for the Maya, versus 19 for the Piro and somewhere between 25 and 35 for the Machiguenga. The profiles for the Piro and Machiguenga males are quite similar, both showing deep deficits in childhood and rising in similar ways through the adult years. The Maya males are a sharp contrast, with deficits that are much more modest in childhood and very low surplus production in adulthood. Their low net production in adulthood is consistent with the higher net production of women, and with the relatively small deficits of Maya children.

**Cumulative Net Production and the Payback Age**

We know, of course, that children begin life completely dependent on their parents for food, and also that at some point in their lives they become economically mature in the sense of producing as much as they consume, and then eventually produce a surplus which is transferred to the younger members of the population. These various stages could be investigated by simple inspection of the age profiles. It is also useful to go beyond the simple inspection of the flows of consumption and production to keep track of the cumulated production and consumption of an individual who moves through the life cycle. Unfortunately our data are cross-sectional, so that only be the assumption of stationary conditions can we make any inferences about changes over the life cycle.

From the point of view of a child, we could simply sum the consumption and production up to successive ages, and that would give the running total. From the broader accounting perspective of a parent, trying to form an idea about the costliness childbearing in general, we would need to take into account the probability of survival to each age. In order to raise one productive 20 year old female, for example, it might be necessary to give birth to, and to feed for a number of years, two female babies, one of whom would die. For this reason, we calculate cumulative survival-weighted net production totals. For some purposes, and in some settings, it might be appropriate to discount these as well. In these settings, where there are no opportunities for borrowing or lending, and investment opportunities are very limited, it is not clear what discounting would mean.

For none of these communities is mortality measured well. For the Piro and Machiguenga we have used mortality data for the forest dwelling (pre-settlement) Ache, a hunter-gatherer horticulturalist group in Paraguay. For the Maya, we have assumed that life expectancy is 45. We have experimented with different levels of mortality, and found that results are not very sensitive to such variations. In the figures we show calculations based on zero mortality as well as the assumptions just given, so the reader can judge the sensitivity of the results to mortality assumptions.
Figure 5 plots the cumulative net production (these should include survival weighting but do not yet; to see the effects of survival weighting, see Figures 6 and 7 which are not standardized). The lines cross the horizontal axis at the age such that the sum of the consumption and production profiles up to that age are equal (in the standardized figures with no survival weighting and no discounting). Survival weighting and discounting would move the cross point to higher ages toward the right, so these payback ages are actually lower bounds (Table 1 below shows a range from the survival weighted to the not-survival weighted payback age). Maya women reach payback at (survival weighted) age 24 or so; Piro in their 40s; and Machiguenga between 55 and 65, out of range of this graph. The Maya males don’t achieve payback until their late 40s, while the Piro and Machiguenga do by 35 and 32, respectively.

**Average Ages of Production and Consumption, and Direction of Net Transfer Flows**

The average age of consumption, $A_c$, is defined in the equation below, and the average age of production, $A_y$, is defined similarly:

$$A_c = \frac{\sum_{x=0}^{x_N} xN(x,t)c(x,t)}{\sum_{x=0}^{x_N} N(x,t)c(x,t)}$$

where $N(x,t)$ is the number of people in the population of age $x$ at time $t$. When $A_c > A_y$, the direction of net transfers is upward from younger to older, consistent with Caldwell’s (1976) assertion for traditional societies. When $A_y > A_c$, the net direction of transfers is downwards, from older people to younger, consistent with the idea that on net, transfers flow to children (see Lee, 1994 and 2000).

Table 2 gives the average ages of production and consumption by sex for the Machiguenga and Piro, based on the actual individual observations on production and consumption for people of specific ages. The direction of transfer flows is very strongly downward, by 10.4 years for the Machiguenga (sexes combined) and by 15.3 years for the Piro. These reflect the heavy and prolonged dependence of children in these groups, and contrast strongly to the four year difference for the Maya reported in Lee and Kramer (2001). The difference in average ages of production and consumption can be interpreted like this: the average calorie of food was produced by someone 15.3 years older than the person who consumed it. These groups provide an extraordinary and extreme example of the downward flow of income in a population (see Lee, 2000, for a discussion of this measure, and other examples).
Table 2. Average Ages of Production and Consumption for the Machiguenga and Piro, by Sex

<table>
<thead>
<tr>
<th>Group</th>
<th>Sex</th>
<th>Ac</th>
<th>Ay</th>
<th>Ay-Ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machiguenga</td>
<td>F</td>
<td>23.32050</td>
<td>31.43206</td>
<td>8.1</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>22.24503</td>
<td>34.32299</td>
<td>12.1</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>22.76238</td>
<td>33.14034</td>
<td>10.4</td>
</tr>
<tr>
<td>Piro</td>
<td>F</td>
<td>20.86943</td>
<td>34.40485</td>
<td>13.5</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>22.11871</td>
<td>38.04922</td>
<td>15.9</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>21.57772</td>
<td>36.88784</td>
<td>15.3</td>
</tr>
</tbody>
</table>

Summary of Age Profiles
Various features of the smoothed age-sex profiles are summarized in Table 1, which has a number of striking features.

Table 1. Summary Features of the Male and Female Age Profiles of the Three Groups

<table>
<thead>
<tr>
<th>Group/Sex</th>
<th>Breakeven Age</th>
<th>Payback Age</th>
<th>Prod Slope</th>
<th>Prime Surplus Ratio</th>
<th>Retire? % age 50+ with prd&gt;con</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machiguenga Male</td>
<td>21</td>
<td>32</td>
<td>.35</td>
<td>2.9</td>
<td>75</td>
</tr>
<tr>
<td>Female</td>
<td>25-35</td>
<td>55-65</td>
<td>.71</td>
<td>1.0</td>
<td>67</td>
</tr>
<tr>
<td>Piro Males</td>
<td>20</td>
<td>35</td>
<td>.33</td>
<td>3.1</td>
<td>100</td>
</tr>
<tr>
<td>Females</td>
<td>19</td>
<td>40's</td>
<td>.65</td>
<td>1.7</td>
<td>80</td>
</tr>
<tr>
<td>Maya Males</td>
<td>17-21</td>
<td>40's</td>
<td>.68</td>
<td>1.2</td>
<td>75</td>
</tr>
<tr>
<td>Females</td>
<td>12</td>
<td>24</td>
<td>.94</td>
<td>1.3</td>
<td>100</td>
</tr>
</tbody>
</table>

- The "elderly", those aged 50 and over, in all cases tend to produce more than they consume. Combining all three groups and both sexes, 18 older people (80%) produce more than they consume and only four (20%) produce less than they consume.
- The breakeven age for males is always around 20, in terms of the flows of production and consumption. For females there is no simple generalization. The Machiguenga females produce close to the amount they consume throughout adulthood. The Maya females begin work early and break even at age 12. The Piro females are like the males, breaking even at age 19. Is the early breakeven for Maya females mainly reflecting methodological differences, particularly the fuller accounting of home
production activities in the Maya data? Or does it reflect the difference between agriculture and mixed foraging and horticulture?

- Among the Machiguenga and the Piro, even at age 20 males are producing only about a third of the output produced by a 40 year old man. Among the Maya, however, at 20 the males produce two thirds of what a 40 year old man does. However, a 40 year old Maya man apparently produces only slightly more than he consumes, whereas a 40 year old man from the other groups produces about three times as much as he consumes. Does this simply reflect the more comprehensive measure of consumption used for the Maya, to include all the home production activities that the women are engaged in, giving less weight to the initial production of agricultural output?

Methods for the Household and Cluster Level Analysis

Chayanov (1925/198**) analyzed the effect of demographic change over the family life cycle on economic circumstance and behavior. The conceptual basis of his analysis is still relevant today, and we will retrace his analytic steps for our study populations. First, he constructed a stylized demographic family life cycle, based on the assumption that a couple married at the average ages for males and females, then had births at an assumed birth interval. We have constructed a stylized family life cycle, based on these parameters for the Maya group, but we also take into account mortality and the average age at which children leave home (see Lee and Kramer, 2001).

Second, Chayanov used age-sex specific Equivalent Adult Consumer (EAC) and Equivalent Adult Producer (EAP) weights to calculate the number of EAC and EAP units in the household at each duration. This is done both for the stylized life cycle just described, and for actual households as reported in the data. He used the ratio of the household EAC to the EAP units to measure the demographic pressure on consumption over the family life cycle. This is known as the Chayanov Ratio. He used weights from standard tables of his day, rather than estimating them directly from his data. We could use our age profiles of production and consumption for this purpose, but this would not be quite right. These profiles already reflect the influence of family demography over the life cycle on production and consumption, and therefore incorporate a behavioral response. Women who are 35-39 typically live in families with many dependent children, and consequently the consumption profile for women at this age may be lower, and production may be higher, than would otherwise be the case. To avoid incorporating these responses to demographic pressure in our measures, we have re-estimated the age-sex profiles using a model with household or cluster multiplicative fixed effects (see appendix). With this procedure, the age-shape of the estimated profiles depends entirely on comparisons made within households, while all variation across households (or clusters) will be absorbed by the estimated fixed effects. The fixed effects remove the influence of all aspects of the households good or bad fortune, not just the demographic pressures. These are not reported here.

Third, Chayanov studied how labor effort varied in relation to the Chayanov Ratio over the family life cycle. He discovered that in his data set, labor effort per adult worker varied in proportion to the Chayanov Ratio, and in this way the level of consumption per EAC was protected and held constant regardless of variations in the household
dependency ratio. In our analysis, we use the estimated household or cluster fixed effect on production to measure the intensity of labor effort, and compare it to the Chayanov Ratio. We do similarly for consumption. Results will be reported below.

Households, Clusters and the Life Cycle Dependency Squeeze

As shown in Lee and Kramer (2001), the Maya experience a significant life cycle squeeze when the ratio of consumers to producers in the household (Chayanov ratio) more than doubles ten to twenty years after marriage, for demographic reasons. In the case of the Maya, the squeeze is countered by an increase in the intensity of labor effort by the workers in the family, as predicted by Chayanov’s Law. However, the response is not sufficient to compensate fully for the increased dependency burden, so consumption per equivalent adult consumer declines. We believe that food sharing is often limited to the household or family level among agriculturalists. We also believe that a response of labor effort to variations in the Chayanov ratio is quite common, as Chayanov suggested. Since children in agricultural settings can be quite productive at early ages, the squeeze is not as strong as it would otherwise be.

In the forager-horticulturalist populations for which we have data, children are much less productive, as discussed earlier. We expect (but have not yet done the analysis) that the Chayanov ratio rises much more strongly in the forager populations than in agricultural populations, so that it would be difficulty to sustain these families at the height of the demographic pressure. Furthermore, the supply of food is more erratic for a single hunter than for an agriculturalist. For both these reasons, food sharing at the level of the household would leave families in a precarious situation, exposed to substantial variation in needs over the family life cycle, and substantial variation in food supply on a day-to-day basis. Perhaps for these reasons, food sharing that cuts across family lines to encompass a larger group may be characteristic of forager-horticulturalists who rely on hunted meat for protein and fat. food sharing among hunter-gatherers often. This is so for the Piro and Machiguenga.

Clusters Smooth Household Variations in the Chayanov Ratio

Figures 8 and 9 plot the Chayanov ratios for clusters in the Machiguenga and Piro groups, and for each cluster (# signs) also show the dispersion of the ratios among the households within the cluster (dots). (Ignore the scale on the Chayanov Ratio). The horizontal line shows the Chayanov ratio for the group as a whole. For both groups, it is apparent that the clusters effectively smooth out most of the variation among their member households. The cluster ratios are relatively close to the horizontal line, and so deviate little from the group average. The most striking examples are clusters 2 and 4 of the Machiguenga, and clusters 6 and 7 of the Piro. Cluster 4 of the Piro has only one household, and experiences a fairly serious squeeze with a ratio 55% above the group average.

Behavioral Response to Variations in Chayanov Ratios

As explained earlier, the intensity of labor effort and the general level of consumption can by measured by the estimated fixed effects for production and consumption in households, for the Maya, and in clusters, for the Machiguenga and Piro. Figure 10 shows a scatter of the cluster fixed effects for production against the cluster Chayanov ratio for
Maya households. There is a weak positive association (correlation is .50), consistent with Chayanov’s Law. The elasticity of this relationship is .9, consistent with the strong form of Chayanov’s Law which posits unity.

Figure 11 shows a similar plot for the Machiguenga (ignore the scale for the Chanaov ratio). Four clusters are grouped at a Chayanov Ratio of around .2 (ignore the scale here, which is harmlessly incorrect), with varying production fixed effects; and there is one cluster with a Chayanov Ratio of around .3, and a correspondingly high labor intensity. The correlation is high at .91, but this is obviously misleading. We can again calculate the elasticity, which is now 2.25, double the unitary elasticity of Chayanov’s Law. Once again, this is obviously very unreliable (sorry not to have a formal regression and confidence intervals here).

Figure 12 shows the same for the Piro. Seven clusters with show no association of labor effort with the Chayanov Ratio, but a single somewhat high outlier has an extremely high labor intensity. Nothing here can be taken as supportive of a positive relationship.

As for consumption (not shown), there is a negative correlation of -.60 for the Maya with elasticity around -.5. For the Machiguenga and the Piro, the correlations are essentially zero.

We have also begun to explore more flexible patterns of response to household fixed effects, permitting some age groups to adjust consumption or production more than others, but do not yet have results to report.

Conclusions
As yet unresolved issues of measurement prevent firm conclusions at this point. These issues include evaluation of production by individuals based on time expended versus food calories acquired, and similarly, relative valuation of different products based on caloric value versus time input. Nonetheless, we suggest the following tentative points, subject to confirmation by subsequent analysis:

• Men and women over age 50 remain net producers (note there is no one over age 65 in our groups).
• In the forager groups, children remain net consumers until around age 20. The same is true for Maya males, but the females reach the breakeven point much earlier, around age 12. Mayan children require much smaller net transfers from parents, perhaps only a third those of the forager children.
• In the forager groups, there is a steep and continuing gradient to male production which does not peak until age 40 or later, at three or four times its level at 20. This is in contrast to female production in all three groups, which does not rise much after age 20, and similarly for Maya males. The steep rise for the forager males may reflect returns to training and experience.
• Most surplus is generated by male foragers, but for the Maya, females generate more than males, and neither generates much.
• Forager food sharing in multi-household clusters effectively smoothes away most of the Chayanovian demographic pressure over the family life cycle, in contrast to the household level sharing among the Maya.

• The Maya respond to the Chayanovian squeeze by increasing labor effort proportionately, and also by greater contributions from their children. The foragers avoid the squeeze by foodsharing at the cluster level.

We speculate, based on studies of other groups as well, that these differences may turn out to reflect a fundamental difference in the returns to investment in human capital (primarily learning to hunt, but also learning to gather) in agriculture versus foraging technologies. Such a difference might underly the differences in children’s productivity, in food sharing arrangements, the relative productivity of men and women, and other differences we have noted. Wider sharing may be necessary to fund the prolonged period of costly investment in children in forager societies. Such a generalization cannot be established on the basis of the work reported here, but may eventually turn out to be true.
References


Lee, Ronald (2002) “Rethinking the evolutionary theory of aging: fertility, mortality, and intergenerational transfers” manuscript.

Appendix: Fixed Effect Estimates, Calculation of the Chayanov Ratios, and Estimation of the Chayanov Response of Production

For a particular group, number each individual in the sample from $j=1$ to $J$. Let $y(j)$ and $c(j)$ be the observed production and consumption of individual $j$ (prior to smoothing). Each of these individuals belongs to exactly one household, with households numbered from $i=1$ to $I$. Each individual belongs to a certain age group, $x$, and has sex, $s$. We can view these three attributes of the individual, age, sex and household membership, as functions of the individual's number, $j$, so we have: $x(j)$, $s(j)$, and $i(j)$. Usually the dependence of $x$, $s$ and $i$ on $j$ will be suppressed in the notation, for simplicity.

We assume that there are true underlying propensities to produce, $\pi$, and to consume, $\gamma$, which are functions only of an individual’s age $x$ and sex $s$. These are not observed directly. We write them: $\pi(x,s)$ and $\gamma(x,s)$. They do not vary by household membership. These propensities are influenced by biology (so that young children have lower production propensities, and likewise lower consumption propensities) and by culture (so that females may be expected to work more or less than males of the same age, the patriarch may be accorded special privileges, and so on).

Within a given household, we believe that there will be a tendency to allocate production tasks and consumption in proportion to these underlying propensities. If there is a pressing need for production in a household, then we expect that all members will have relatively high production in relation to their respective $\pi(x,s)$ values. If the household experiences adversity, then we expect that all members will consume a relatively low amount relative to their respective $\gamma(x,s)$ values. These special household effects could reflect the particular age-sex composition of the household, as emphasized by Chayanov. They could also reflect particular good fortune or bad fortune experienced by the household. When bad fortune takes the form of a household member sick or disabled, then patterns of work and consumption will deviate from our assumption that all will tend to move in the same direction.

Estimation of Fixed Effects Models

These considerations suggest the following model for estimating the unobserved values $\pi$ and $\gamma$. It is understood that $x,s$ and $i$ actually refer to $x(j)$, $s(j)$ and $i(j)$.

$$y(j) = F(i)[\pi(x,s)]e^{\epsilon(j)}$$

$$c(j) = G(i)[\gamma(x,s)]e^{\eta(j)}$$

Here, $F(i)$ is the multiplicative amount by which production for all members of this household, of all ages and both sexes, is unusually high or low. Similarly, $G(i)$ is the multiplicative amount by which consumption of all members of household $i$ is unusually high or low.
Estimation is easier if logarithms are taken of both sides of the equation:

\[
(1.3) \quad \ln[y(j)] = \ln[F(i)] + \ln[\pi(x,s)] + \epsilon(j)
\]

\[
(1.4) \quad \ln[c(j)] = \ln[G(i)] + \ln[y(x,s)] + \eta(j)
\]

In this specification, \(\ln[F(i)]\) and \(\ln[G(i)]\) are household fixed effects. They indicate whether people in this household in general are working more or less, and consuming more or less, than would otherwise be expected, or relative to some arbitrarily chosen reference household. With this specification, \(\pi\) and \(\gamma\) are estimated solely on the basis of relative work efforts and consumption amounts for people coexisting within the same household at the same instant.

It would be impossible, with a sample this small, to estimate the full range of age effects together with household effects. We can achieve improved efficiency of estimation, with little loss of detail, by letting \(x\) represent age groups, as follows:

0-4, 5-9, 10-14, 15-19, 20-24, 25-34, 35-50, 50+

That gives 8 values of \(\pi\) and another 8 values of \(\gamma\) to estimate for each sex. In addition, household fixed effects must be estimated for each of production and consumption.

We need to make an arbitrary assumption of value for one of the age-sex categories of \(\gamma\) and likewise of \(\pi\). Otherwise, there is no unique solution and the equation cannot be estimated. This is because we could add some value to \(G\) and subtract it from every instance of \(\ln(\gamma)\), for example, and these would be identically equal. So assume that \(\pi(15-19) = 1.0\) for girls, and similarly assume that \(\gamma(15-19) = 1.0\) for girls. Similarly, we must omit some household membership category, for the usual reasons with categorical variables.

**Construction of Chayanov Ratios**

Let \(H(i,x,s)\) be the number of members of household \(i\) that are in the age category \(x\). Then the weighted sum of consumers in the household, \(C(i)\), is given by:

\[
(1.5) \quad C(i) = \sum_{x,s} H(i,x,s)\gamma(x,s)
\]

The weighted sum of household producers, \(Y(i)\), is defined similarly. Then the ratio \(C(i)/Y(i)\) is the Chayanov Ratio. This can be calculated either for actual households or for the stylized household. If for the stylized household, then the ratio will vary over the duration since formation of the household, in which case we can take \(i\) to refer to the household duration.
Labor and Consumption Intensity in Relation to the Chayanov Ratio
The household fixed effects, \( F(i) \) and \( G(i) \), measure the extent to which members of household \( i \) produce more, or consume more, than is typical for people of their ages and sexes. Thus the estimated household fixed effects can serve well as measures of work intensity and consumption intensity in each household. To assess the response of these intensities to demographic pressures over the household life cycle, we can plot the fixed effects against the Chayanov Ratio, or regress the fixed effects on the Chayanov Ratio.