Title: Bargaining between the sexes: Outside options and leisure time in hunter-gatherer households

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Abstract (150 words)

We discuss gendered division of labour in nuclear households as a bargaining problem, where male and female partners bargain over labour inputs and resulting leisure time. We hypothesize that outside options - an individual's fallback options for welfare outside their household, such as kin support - affects this bargaining process, providing those with greater outside options more leverage to bargain for leisure time. In two hunter-gatherer populations, the BaYaka and Agta, we take social capital as the determinant of outside options, using a generative model of the Nash bargaining problem and Bayesian multilevel logistic regression to test our hypothesis. We find no evidence for an association between social capital and division of leisure in either population. Instead, we find remarkable equality in the division of leisure time within households. We suggest the potential role of sex-egalitarian norms, non-substitutability of subsistence labour, bilocality and behaviors which maintain gender equality in immediate-return hunter-gatherers.

1. Introduction

Households of pair-bonded males and females have long been argued to be a site for cooperation, due to shared fitness interests in the rearing of offspring (Lovejoy, 1981). Given the long developmental period of the human offspring, paternal investment - especially during the critical period when females are still engaged in reproduction and lactation (Marlowe, 2003) - can be an important contributor for offspring survival. Cooperation between hunter-gatherer males and females also provides a diversified diet, with males majorly procuring fats and proteins, and females gathering carbohydrate-rich foods (Marlowe, 2007), both requiring considerable specialisation (Gurven & Hill, 2009). So, if males specialise in hunting for high-risk, high-reward foods such as big game, females can invest in gathering wild foods, an activity more compatible with mothering, both still sharing the goal of successful rearing of the joint offspring. Nonetheless, each member of the pair-bond also attends to their own interests, which might fall outside of household provisioning. For instance, Hawkes argues that male hunting much more likely serves the purpose of showing off one's phenotypic quality to potential cooperation partners and mates, even more than provisioning for one's family (Hawkes, 1991; 2019; Hawkes et al., 2014; for criticism see Stibbard-Hawkes, 2019). Females on the other hand, would bargain for higher male provisioning, so they

can spend time in further reproductive effort. A household is, therefore, the locus of both, important cooperative ventures with coordination problems to be solved, and partially misaligned interests.

Sexual division of labour (DoL) within a household is shaped by a combination of the joint interest of rearing successful and healthy offspring, and bargaining dynamics between the private interests of individuals. It is the latter that forms our phenomenon of interest and that we investigate in this study. Gurven and Hill modelled this within a bioeconomic bargaining context, with complementary labour allocations of individuals shaped by points where either individual can threaten to leave the relationship (one's viable threat points; Gurven & Hill, 2009; Gurven et al., 2009). We use this model to predict, at the level of individual households, the impact of each partners' social capital on their relative amount of work effort (measured by leisure time) invested in household labour.

Bargaining problems have been a popular characterization of household DoL, where partners often distribute household tasks in a complementary manner (Manser & Brown, 1980; Agarwal, 1997; Ott, 2012). For instance, if one partner does the cooking, the other must clean, to successfully host a dinner. If both cook and nobody cleans, both are left with a messy kitchen. The key question asked in such complementary division of tasks is, who does *what,* and how is the division of payoffs determined*?* Bargaining power provided by outside options - operationalized as, options for payoffs that an individual can have should they choose not to participate in the current cooperative venture - has been suggested to be an important determinant of DoL (Knez & Camerer, 1995; Schmitt, 2004; Binmore et al., 1991; Binmore & Eguia, 2017; O'Connor, 2019). According to the bargaining approach, the partner with better outside options will be able to bargain for a more advantageous allocation of tasks within their household. Outside options can be provided by factors, such as one's opportunities for remarrying, the ease of obtaining resources for oneself, social support from kin, etc. In our study, we consider social capital - here, a measure of how many of one's campmates are willing to share resources with them - as the major determinant of outside options and test whether having higher social capital provides an individual advantage in leisure time distribution within their household. We further run a robustness check with additional measures of real-world sharing and social networks, testing their effects on leisure time distribution in both populations.

When there are differences in outside options, it can lead to task distributions that advantage one group over another – often leading to unequal payoffs. Such distributions can become mutually acceptable and in the longer run, culturally stable (O'Connor, 2019), such as the case of patriarchal behaviours in plough-based economies. Ploughing – usually carried out by men due to greater average upper body

strength – has been said to afford men more bargaining power than women, as they control the crop production. This economic stability provides them better outside options, and is suggested to contribute to patriarchal societies (Alesina et al., 2013; but see Burton & White, 1984). In turn, women's dependence on men can increase, and their mobility and decision-making can become severely limited (Djurfeldt, 2021). Within industrialised societies, economic factors like, employment prospects (Abraham et al., 2010; Brines, 1994), relative earnings of spouses (Klein & Barham, 2018), resource dependency (Greenstein, 2000) and education gap (Fengdan et al., 2016; Ma & Piao, 2019) have been seen to provide bargaining power and shape housework distributions. Game theoretic models of households report similar effects (Breen and Cooke, 2005). Additionally, social and institutional factors like inheritance and divorce norms (Baland & Ziparo, 2018), and national gender ideology (Mandel et al., 2020; Brines, 1994), can also determine outside options. Despite substantial exploration of household bargaining in large-scale societies, the phenomenon remains understudied in small-scale societies. Here, we study this phenomenon in two immediate-return hunter-gatherer populations - the Mbendjele BaYaka from Congo and the Agta from the Philippines - to understand how DoL within pair-bonds is shaped within small-scale and gender-egalitarian populations.

Social capital is the main constituent of wealth in such immediate-return hunter-gatherer societies, which do not accumulate much food and material resources (Borgerhoff Mulder et al. 2009). We derive an experimental measure of social capital from gift-giving games, showing for each individual, how many campmates are willing to share resources with them. This measure is associated with increases in one's mate value and polygyny potential (Chaudhary et al., 2015), buffering food risk in times of resource scarcity, increase in body mass index and contributing to female fertility (Chaudhary et al., 2016). Other measures of social capital contribute to one's food-sharing networks (Dyble et al., 2016), correlate with enhanced fertility and offspring survivorship (Page et al., 2017) and aid in developing one's information networks (Migliano et al., 2017). Social capital, therefore, can be seen as the real-world measure that shapes individuals' outside options in these societies and provides bargaining power, representing the support individuals can get if they leave their household. We further corroborate the robustness of this measure in capturing one's social capital, by adding additional measures of social capital - campmate networks for Agta and food transfers in BaYaka - for both populations. Food-sharing measures, in other closely related BaYaka populations, have been shown to be correlated with status (Gettler et al., 2023), again contributing to one's social capital. To compare labour division inputs, we measure leisure time allocation. Though energy expenditure in labour can have a direct impact on how much leisure time one requires, this is also difficult to measure as there can be great individual variations in performance of

tasks and calculations of calorie expenditure. Thus, the measure of leisure time is most commonly used currency in evolutionary modelling of time and energy expenditure of behaviours, and also exploited by large-scale national and international surveys analysing public welfare across countries, like the International Social Survey Programme (ISSP; Braun et al., 2008) and National Survey of Family and Households (NSFH; DeMaris & Longmore, 1996). We therefore hypothesise that in the households of these immediate-return hunter-gatherers, the partner with more social capital has better outside options, and so will be able to bargain for a greater share of household leisure time.

2. Materials and Methods

This research was approved by the UCL Ethics Committee (UCLEthicscode3086/003), and carried out with permission from the Ministry of Scientific Research, Congo. In Agta, fieldwork permission was granted by local government units, including Mayors of the Municipalities visited, and the Department of Environment and Natural Resources (DENR) as the research took place in a protected area. All BaYaka and Agta communities agreed to participate, and informed consent was obtained from all individuals.

2.1. Participants

2.1.1. The Mbendjele BaYaka:

The Mbendjele are a subgroup of the BaYaka Pygmies, who speak Mbendjele. They live with kin and non-kin in multi-family camps (*langos,* size: 10 - 80), with nuclear families residing in individual huts (*fumas)*. Average genetic relatedness in camp is low due to bilocality and fluid movement of individuals between camps (Dyble et al. 2016). These groups are heavily dependent on cooperative activities such as food sharing, collaborative foraging and allo-parenting (Chaudhary et al. 2016; Dyble et al. 2016; Boyette et al., 2020). Some groups occasionally engage in wage-labour (Knight et al., 2021), though this is not the case for any of the communities we study, who remain in mobile forest camps. These hunter-gatherers largely consume the food they hunt and gather within a few days, engaging in an immediate-return economic system and therefore, have very little accumulated material wealth or resources (Lewis, 2017).

Sex Egalitarianism

The BaYaka are some of the most sex-egalitarian populations recorded in the ethnographic record (Noss & Hewlett, 2001). Males and females, though forming biologically and socially distinct categories, have similar social standing, equal decision-making power and no taboos allowing one sex to dominate. They are often described as being 'assertively egalitarian' (Woodburn, 1982). Each sex uses rituals to demonstrate their collective strength and playfully taunt or mock the other; the combined power of each sex neutralises that of the other and prevents domination (Lewis, 2013; Bombjaková, 2018). Egalitarianism arises from ritualised and symbolic inter-sex bargaining, which provides a particularly interesting setting for our study. Men hold the few titles of *kombeti* (elder spokesperson), *tuma* (skilled elephant-hunter), and *nganga* (healer), but these carry no authority. Women usually challenge attempts of male dominance and exercise great influence over decision-making. This egalitarianism is often concomitant with bilocality, where married couples may live with either the husband's or the wife's kin (Dyble et al. 2015); and the marital system is predominantly serially monogamous (Chaudhary et al. 2015). Households are nuclear and easily dissolvable, with new huts being set up very quickly. Women have considerable partner choice, freedom of movement within and between camps, and can survive even if they remain single. All of these provide them with outside options, and have important implications for bargaining.

Sexual Division of Labour

Despite equal social standing, men and women do play complementary roles in their camps. Women are valued for their ability to bear life, maintain solidarity in community enforcement of social norms, whereas men are valued for their physical strength, providing meat to sustain others, and procuring dangerous but desired products (Lewis, 2017). Men typically hunt and collect honey, whilst women contribute by fishing, gathering yams, and other sources of carbohydrates and micronutrients, though the gathering activities remain interchangeable. Husband and wife share childcare, subsistence, leisure and other ritual activities, and both have equal decision-making power in marriage and cohabitation choices (Dyble et al., 2015). Kin and non-kin engage in allocare of children. Fathers among the Aka, another BaYaka subgroup, have been found to provide more direct childcare than in any other recorded culture (Hewlett, 1993). In addition, children also grow up in shared caregiving environments with support across families (Boyette et al., 2020), all of which considerably frees up mothers for other foraging activities. Such high female contribution to subsistence and economic production has been postulated as an important driver of sex-egalitarianism (Noss & Hewlett, 2001).

Demand Sharing and Social capital

The BaYaka practice demand-sharing, where anyone in need of a resource, particularly food, can demand it from the one possessing it, and it is considered the possessor's duty to share (Lewis et al., 2014). Demand sharing hypothetically ensures natural differences of skill and luck are not converted into differences in status, authority or rank, maintaining a non-hierarchical social structure (Woodburn, 1982; Lewis, 2008; Lewis, 2017). However, cooperation and food transfers are not always evenly distributed within camps and follow patterns based on kinship and reciprocity (Thompson, 2018; Chaudhary et al., 2016; Gettler et al., 2023). Consequently, individuals with more cooperative alliances based on popularity — social capital — may have greater bargaining power in interactions with their partner due to their superior outside options. We note that prevalence of both the practices might lend a point of contention for bargaining dynamics, with demand sharing lowering the need for having social capital, and structured sharing based on cooperative alliances, increasing it.

2.1.2. The Agta

The Palanan Agta are a group of small-scale hunter-gatherers residing in northeast Luzon, ~~the~~ Philippines. They are characterised by high mobility, small camps with low genetic relatedness and egalitarian social relations (Minter, 2010; Dyble et al., 2015). Their economy is predominantly based on fishing (riverine and marine), gathering and some hunting in the tropical forests of the Northern Sierra Madre Natural Park. They also engage in trade with neighbouring farmers, logging, and now increasingly in agricultural and other paid labour (Griffin, 1996). Some households are much more sedentary than others (Page et al. 2016; Smith et al. 2016). There is also an impact of outside institutions, such as schooling, church and healthcare (Page et al., 2018). Camp sizes can vary between solitary dwellings (7 individuals) to large camps with 26 houses (156 individuals), with an average of seven houses (49 individuals; Smith et al., 2017).

Sex Egalitarianism

The Agta are highly egalitarian, similar to the BaYaka. Autonomy in decision-making is central to their lives and all adults are afforded equal standing without stratification or hereditary positions (Minter, 2010; Griffin, 2000). Some more experienced and influential members sometimes ensue the role of advice-providers or conflict-mediators (Headland 1987; Griffin 1996; Minter, 2010), but none in formal positions of authority. Subsistence activities are carried out by both males and females, though some activities might be more gender-specific than others. Agta women have been formerly famed as female hunters, combining hunting activities with no decline in fertility. Brightman observed that 85% of the

Nanadukan Agta women of Luzon hunt, regardless of whether they are menstruating, pregnant or have nursing responsibilities (Brightman, 1996). In the current population however, hunting forms less than 5% of all subsistence activity and is almost entirely male-only (refer SM of Dyble et al., 2019). Fishing is done by both males and females, with males mainly spear-fishing and females beach-combing to collect octopus and other shellfish. Gathering is predominantly done by women. Over the years there has been growing involvement with agricultural and paid labour, also engaging both males and females (Dyble et al., 2019).

Marriage and Households

Men and women have autonomy in choosing their partners and young individuals often engage in 'trial marriages' to test compatibility and partnership values, before committing to an individual. There are rarely large age differences between husbands and wives (Dyble et al., 2021) and post marriage, both men and women have equal decision-making power on where the married couple stays (Dyble et al. 2015; Minter, 2010). Men also pay bride service (*magservi*) for the wife-to-be's family (Smith, 2017) by helping out in various domains, including the domestic. The Agta are serially monogamous (Minter, 2010; Headland, 1987) and divorce becomes exceedingly rare once a child is born. Allomothering in the form of childcare is a common occurrence in the Agta, where close kin or non-kin individuals care for the dependent child, and in turn benefit mothers, who can spend more time on economic activities and leisure (Page, 2021). Given their bilocal nature, Agta children become equally likely to reside with either their mother's or their or father's family.

Sharing and Social capital

The Agta foragers cooperate intensively, with regular food-sharing occurring within and between households (Dyble et al., 2016), and campmates cooperating for foraging and other subsistence activities (Smith et al., 2019), as well as childcare (Page et al., 2019). One's popularity in camp has been associated with the benefits they can expect to receive from others. Being skilled in hunting and fishing, being a respected storyteller and yielding decision-making influence, can greatly contribute to one's value as a cooperation partner, which is reflected in one's social capital (Smith et al., 2017). The position one has in their social networks has even been associated with fertility (Page et al., 2017). Social capital is therefore likely to shape Agta behaviour considerably, and in the absence of material wealth, is the most appropriate determinant of an individual's ability to survive outside of their household.

2.2. Data Collection

We analyse pre-collected ethnographic data, both observational and experimental. Data was collected from Mbendjele BaYaka communities residing in the Sangha and Likoula districts of Northern Republic of Congo, and the Palanan Agta community residing across the Northern Sierra Madre Natural Park in northern Philippines. Fieldwork for the BaYaka was conducted between April - June 2013 and March - July 2014 and for the Agta over two periods of April to June 2013, and February to October 2014.

Data was collected from three BaYaka camps, and complete data was available from a total of 46 individuals, i.e., 23 couples. For the Agta, time allocation and social capital data was available for a total of 108 adult individuals, who formed 54 couples, from 10 camps. No statistical methods were used to pre-determine sample size, which was determined by the size of the communities the ethnographers had the opportunity to study.

2.2.1. Calculating Social capital (determinant of outside options)

We measured social capital by the honey-stick giving game in the BaYaka, where each individual must distribute three sticks of honey to any campmates as they wish, except themselves (detailed protocol can be found in Chaudhary et al., 2015). *The total number of honey sticks received by an individual, standardised by camp, is considered as that individual's social capital z-score.* Social capital z-score = (number of sticks - camp mean)/ camp std. dev. In the Agta, social capital was measured by the Sharing Game, where individuals were shown photos of 10 randomly chosen campmates amongst whom they had to divide rice tokens, in any manner they wished (detailed protocol can be found in Smith et al., 2016). *The total number of rice nominations an individual received, divided by the number of times their photo was shown to campmates, then standardised by camp, is considered as an individual's social capital z-score.* In the Agta, nobody in camp 9 shared any rice tokens with anyone and thus all individuals were given zero as their social capital score.

For both populations, the individual social capital z-scores are then used to calculate our final measure of the predictor variable 'difference in social capital between household partners; that is: male z-score - female z-score.

We ran additional analyses with other measures of social capital. In the BaYaka, we use real-world food transfer data. For this measure, households were observed by the researcher on site, recording all food

produced by a focal household and the number of camp members from whom each individual received food in real-world transfers (detailed protocol can be found in Chaudhary et al., 2016). Observations were done over a series of 2 - 4 hour time blocks, total observations spanning 24 or 36 hours per household depending on the camp. In the Agta, we use campmate-network data; all adult Agta individuals were asked to name up to five individuals that they would most like to live with. This was done in an interview format. These measures are used primarily as a robustness check for the primary measures of social wealth, honey-stick giving game and Sharing Game.

2.2.2. Calculating Leisure Time

We calculate an individual's leisure time by the total number of hours they spent resting or socialising. Data was collected using a scan sampling method for both the populations, where activities of each camp member is recorded as a 'snapshot' in time (Thompson, 2018; Dyble et al., 2019).

For the BaYaka, the data consists of 9094 scans collected over 35 days. Scans included what each individual in camp is doing between 6am and 6pm at one-hour intervals. Any individual above 18 not seen in camp, was assumed to be engaged in foraging/work or collecting water/firewood, since this is the only reason individuals leave camp during the day.

For the Agta, time-allocation was obtained by conducting four scans each day, with the first scan between 06:30 and 09:00 in the morning and three more at three-hour intervals. This resulted in a total of 10,706 scans, including individual activities and proximity with other adults. When an individual was out of camp, researchers asked those in camp what the absent person was doing, corroborating this when the individual returned (Dyble et al., 2019).

In both populations, activities recorded were broadly categorised as foraging, making and manufacturing, food processing, cleaning, carrying and collecting, childcare, socialising, resting, playing and other (Thompson, 2018). We use the raw count of resting, socialising, playing, and sleeping scans for each individual, to calculate leisure hours. Individual leisure hours are then used to derive our final measure of the response variable, that is male's portion of household leisure budget i.e., male leisure/ (male leisure + female leisure)

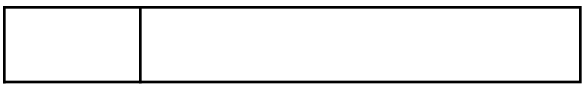
2.3. Data Analyses

We develop two data analysis strategies. The first strategy develops a game theoretic model of household bargaining. We then estimate features of the utility function that plausibly shapes the household division of labour in these societies. Following the recommendation of (Smaldino, 2020; McElreath, 2020, chapter 19), we find it more fruitful to fit the theoretical model directly rather than fitting a generalised linear model. The parameter estimates obtained through this strategy have theoretical meaning and the errors of the model are informative. However, due to computational limits, we can only explore game theoretical models with a small number of parameters. To explore the potential effect of confounding variables in our observational dataset, we turn to a multilevel logistic regression.

2.3.1. Generative Model

We utilise the Nash bargaining game to model the relationship between outside options and the household division of labour. In the game, two players divide up a shared pool of leisure time. Each player has a strategy which represents what proportion of the available leisure time they want. If the sum of the two players' strategies are less than or equal to the total pool, they get exactly the proportion they want. For example, if each player asks for $\frac{1}{2}$, those are compatible demands. Similarly, if one player asks for $\frac{1}{3}$ while the other asks for $\frac{2}{3}$, those are also compatible. However, if the sum of the strategies is greater than total pool, then the household dissolves and players must pursue their outside option; so if both players ask for $\frac{2}{3}$ of the leisure time then players cannot settle on an acceptable division of labour.

We can assign utilities to these outcomes in two steps. First, for all compatible demands, we assume players prefer more leisure time to less and that their utility grows linearly with the amount of leisure time. Second, we can estimate the utility assigned to outside options using a procedure described below. We call this utility a disagreement point. Table 1 displays a simplified version of the game in which players are restricted to only three demands: low, medium, and high and the pool of leisure hours is 10. We'll use this table to provide intuition for the model in a simplified setting while introducing a more general formal description



		Player 2		
		Low	Medium	High
Player 1	Low	4,4	4,5	4,6
	Medium	5,4	5,5	d_1,d_2
	High	6,4	d_1,d_2	d_1,d_2

Table 1: Payoff matrix for the Nash bargaining problem showing payoffs for low, medium and high demands for leisure time by players. Cells along the counter-diagonal represent states of equilibria, and d_1 and d_2 represent disagreement point payoffs for player 1 and player 2, respectively.

Deliberation dynamics

For selecting the most attractive equilibrium, we use a dynamic approach, which explicitly models the learning or deliberative processes that lead agents to take certain actions (Samuelson, 1988; Skyrms, 1990), grounding the equilibria concepts in cognitive science (Binmore, 1989; Gintis, 2014). An exemplar of the dynamic approach is known as the Darwin dynamics, which we adopt in this project (Skyrms, 1990). Suppose that two agents play the bargaining game given in table 1 and are uncertain as to what they will do. We represent this by a uniform probability distribution over possible actions. Player one's distribution is the vector, $\vec{p} = \left[\frac{1}{3}, \frac{1}{3}, \frac{1}{3}\right]$. Player two's distribution is the vector, $\vec{q} = \left[\frac{1}{3}, \frac{1}{3}, \frac{1}{3}\right]$. Each player deliberates through the problem over a number of rounds to select a unique equilibrium. The deliberation happens in a number of steps.

First, player one calculates the expected utility of each one of their strategies. They consider each strategy available to player two and calculate the utility that would result from each pair of strategies. Then player one weighs each utility by the probability that player two takes the respective action. Let $eu_1(s_i)$ represent player one's expected utility of strategy *i* and let $u_1(s_i, s_j)$ represent the utility to player one, given a pair of strategies. The expected utility then is given by (1):

$$eu_1(s_i) = \sum_j^3 u_1(s_i, s_j)\, \vec{q}_j \quad (1)$$

For example, suppose player 1 is calculating the expected utility of a medium demand and we assume $d_1 = 1$. That amounts to $5\frac{1}{3} + 5\frac{1}{3} + 1\frac{1}{3}$. Player two follows the same procedure to calculate the expected utilities of each of their own strategies.

Second, they calculate the probability distribution they should assign to each of their strategies on the next round of deliberation, by a process similar to Bayesian updating. The principle is that strategies that have higher expected utility should receive more weight in the next round of deliberation.

The probability player 1 assigns to strategy *i*, on the next round of deliberation is given by:

$$\vec{p}_i = \vec{p}_i \frac{eu_1(s_i)}{\sum_i^3 eu_1(s_i)p_i} \quad (2)$$

The denominator represents the average expected utility of each of their strategies while the numerator represents the expected utility of the current strategy. If the ratio of the two is larger than one, the probability attached to a strategy grows from one round of deliberation to the next. In intuitive terms, players grow more confident in strategies that do better than average. For example, suppose player one is calculating the probability they should assign to strategy 2. The expected utility of this action was $\frac{11}{3}$. The average expected utility across all strategies is $\frac{31}{9}$. So in this case, player 1 should be more willing to choose strategy 5 in the next round of deliberation. Player two carries out the same deliberation, except that they are updating $\vec{q}$.

Third, the players both repeat steps one and two. On the next round of deliberation, players consider the updated probability distributions derived from round one. This process is repeated until the probability distributions concentrate all the weight on a single pair of strategies - the dynamic solution to the game. These dynamics exhibit several intuitive properties. When an individual has a low disagreement point (i.e., low utility assigned to their outside options), they will tend to favour low risk strategies like ‘demand 4’ early in the deliberation process. Players with high disagreement points can afford to take on more risk and their distribution will favour strategies like “demand 6”. These initial shifts in the deliberation can

become self-reinforcing. When you know the other player is likely to demand 6, your best strategy is to demand 4.

The full data analysis proceeds the same way as the simplified one presented above, except we allow players to have as many strategies as there are available leisure hours. One strategy asks for 1 hour, the next asks for 2 hours and so on.

Following this, the model makes a simple prediction for equilibrium selection: when an individual has a higher disagreement point relative to their partner, they will be able to enjoy a greater share of leisure time relative to their spouse, by virtue of their greater bargaining power.

Rationale and Limitations of the model

One key source of robustness for this model is that substantially different dynamics - from the deterministic Darwin dynamics model and the stochastic reinforcement learning models - make identical predictions (Börgers & Sarin, 1997). Both also predict equilibrium behaviour in laboratory experiments (Camerer, 2003, chapter 6; Crawford, 1995; Erev & Roth, 1998). We do not intend the mathematical deliberation dynamics to represent how people actually come to make their decision. The actual processes might look heterogeneous: some households might vigorously argue aloud, providing continuous information to one another about how they are making up their minds and why; others might silently and implicitly negotiate, leaving some chores clearly unfinished to prod the other partner into picking up their slack. From the right level of abstraction, these diverse practices are the same thing and the model is well motivated so long as humans perform as if they decide according to deliberation dynamics.

The model is limited due to its assumption that players start from a place of total uncertainty, and prior expectations - for example, from cultural gender norms - play no role. This assumption is necessary to let the outcome be driven by individual-level bargaining processes. , and not pre-existing beliefs. Another limitation arises from the assumption that people are behaving at equilibrium when observed. The data cannot tell us which stage of bargaining a couple is at, when observed. We assume households tend, on average, toward the equilibrium predicted and errors should be symmetrically distributed around the prediction.

Statistical estimation of disagreement points

Disagreement points are unobserved theoretical quantities, representing the utility of one's outside options. We construct a function which maps the social capital (sc) - our measure of outside options - of individual 1, in household *i,* onto the disagreement point.

$$d_{1,i} = budget_i(a + b * sc_{1,i}) \quad (3)$$

The ($a + b * sc_{1,i}$) term on the equation is multiplied by each household's total budget, to scale the disagreement point based on widely varying budgets across households. Social capital varies by individual, budget varies by household, and *a* and *b* are shared across households. We also interpret disagreement points in a way that makes them comparable with leisure hours. If a person is estimated to have a disagreement point of 2, then they should prefer leaving a relationship to staying in one that only provides 1 hour of leisure time. The assumption that utility scales linearly with leisure hours is questionable. Many well-studied utility scales exhibit diminishing marginal returns. However, to keep the model sufficiently simple and to reduce overfitting risk, we work with a linear utility on the assumption that this will provide a sufficiently good approximation of utility functions with more complex functional forms.

We estimate *a* and *b* from the data through a maximum likelihood estimation strategy. We use a grid search over plausible values of *a* and *b* to find the pair of values that maximises the likelihood of the data. This yields an estimate of the disagreement point for each household. Given that leisure hours come in integer valued increments and must be either zero or positive (based on our data measurements, which are available in one or four-hour increments), we assume the outcomes are binomially distributed around the predicted distribution of leisure hours (McElreath, 2020, Chapter 11). We use the observed budget as the *n* parameter in the binomial distribution and the proportion of the predicted leisure hours over the budget as the *p* parameter. The full statistical model can be summarised using the standard model notation.

$$male\ leisure\ hours \sim Binomial(n = budget_i,\ p = p_i) \quad (4)$$

$$p_i = deliberation\ dynamics(budget_i,\ d_{1,i},\ d_{2,i}) \quad (5)$$

$$d_{1,i} = budget_i(a + b * sc_{1,i}) \quad (6)$$

$$d_{2,i} = budget_i(a + b * sc_{2,i}) \quad (7)$$

We conduct a series of small, computationally efficient grid searches to identify an appropriate grain for the search grid, as well as regions of the parameter space that likely contain the peak of the likelihood distribution.

In the BaYaka, we find that there are three households where one partner has both substantially greater social capital and a substantially greater number of leisure hours than the other partner. These households turn out to be highly influential which can lead to overfitting of the slope parameter. To test the robustness of our results, we also fit a model of overdispersion to the data, by replacing the binomial outcome distribution with a beta-binomial, which has a parameter, *d*, controlling the amount of dispersion. To estimate this overdispersion model, we first fixed the slope and intercept parameters at the maximum likelihood points found through the previous grid search. Second, we searched a grid of integers from 1 to 120 to find the *d* parameter that maximised fit to the data. We found d = 11, indicating substantial overdispersion. Third, we explored how the slope and intercept parameters change when using an overdispersed outcome distribution by rerunning the grid search described above. Thus, we find new maximum likelihood points and report the results.

For the Agta, we again first conducted preliminary searches of the parameter space to identify an appropriate region for applying a more precise grid search algorithm. We also checked for overdispersion with the same procedure described above and found little evidence that the data departs from a binomial distribution.

This generative model provides a direct evaluation of the theoretical model, reducing the risk of overfitting and data-dependent analysis practices (Gelman and Loken, 2013). Further, it improves the interpretability of our parameter estimates, which linear regressions cannot provide. Disagreement points are theoretical quantities and estimating the parameters connecting social capital (outside options) to disagreement points, is important for inferring the amount of leverage each partner has. We also test the reliability of our estimation procedure, by producing synthetic data assuming that the model is the true data-generating process. Then we run maximum likelihood estimation on the synthetic data to see if we can reliably recover the sampled parameters (see SI section 3).

2.3.2. Statistical Model - Bayesian Multilevel Logistic Regression

Given the small size of the sample, we used a Bayesian multilevel logistic regression to estimate effects of confounding variables such as average age of couple, age difference (male-female) of couple, number

of dependants (though dependants were not included as confounders in the Agta, as they have been shown to not impact leisure time in adults; Dyble et al., 2019) and camp effects, using weakly informative priors and validating the plausibility of the prior distribution with visual checks (refer SI section 2). The main predictor variable is the difference between male and female social capital z-scores. The effect of social capital was varied by camp. Our response variable is the male's relative leisure time (male leisure hours/ (male + female leisure hours).

Since Bayesian methods don't have minimal sample size requirements (Gelman, 2006), the model can be fitted for the BaYaka, which has three camps, as well as the Agta, which has ten.

3. Results

We observe that males and females tend to divide leisure time almost equally, in both BaYaka and Agta households. In the BaYaka the average split of household leisure budget is 0.550 (s.d. = 0.146), and in the Agta, it is 0.487 (s.d. = 0.145), with 0 suggesting that the female has all the leisure time, and 1 suggesting all leisure for the male. We did not find a strong correlation between the social capital of males and females within a household. There is a small positive correlation (Pearson's r (21) = 0.314, p = 0.145) among BaYaka couples and no correlation (Pearson's r (54) = 0.036, p = 0.797) among Agta couples. In the BaYaka, males also tend to have higher social capital on average than females, with the average difference being 0.59 (s.d. = 1.146). The difference is nearly null in the Agta at -0.05 (s.d. = 0.145), suggesting that the average female might have slightly more social capital than the average male. Further, we look at the association between partners' social capital and their relative leisure time to test our hypothesis

3.1. Generative Model

The generative model provides a measure of disagreement points, as a linear function of social capital and then uses the disagreement points to predict how leisure time is divided in each household, depending on total leisure budgets. For estimating disagreement points, we explore the maximum likelihood values of *a* (intercept), which represents the baseline cost of dissolving a household, and slope *b,* which represents the increase in disagreement point corresponding with one z-score increase in social capital.

In the BaYaka ($N_{household}$ =23), the maximum likelihood values of *a* range from -0.0375 to 0.1500, and *b* ranges from 0.015 to 0.019 (refer to SI), suggesting a 1.5 - 1.9% increase in disagreement point, when the

social capital z-score increases by 1. We select (a = -0.0375, b = 0.019) as values with best fit to the data, and plug them into the deliberation dynamics to predict the split of leisure time in each household. We compare these with observed splits in the households (Fig 1). On average, a 1 z-score increase in social capital, increases one's leisure time only by 1% of the household budget, suggesting a minimal effect of social capital on leisure distribution.

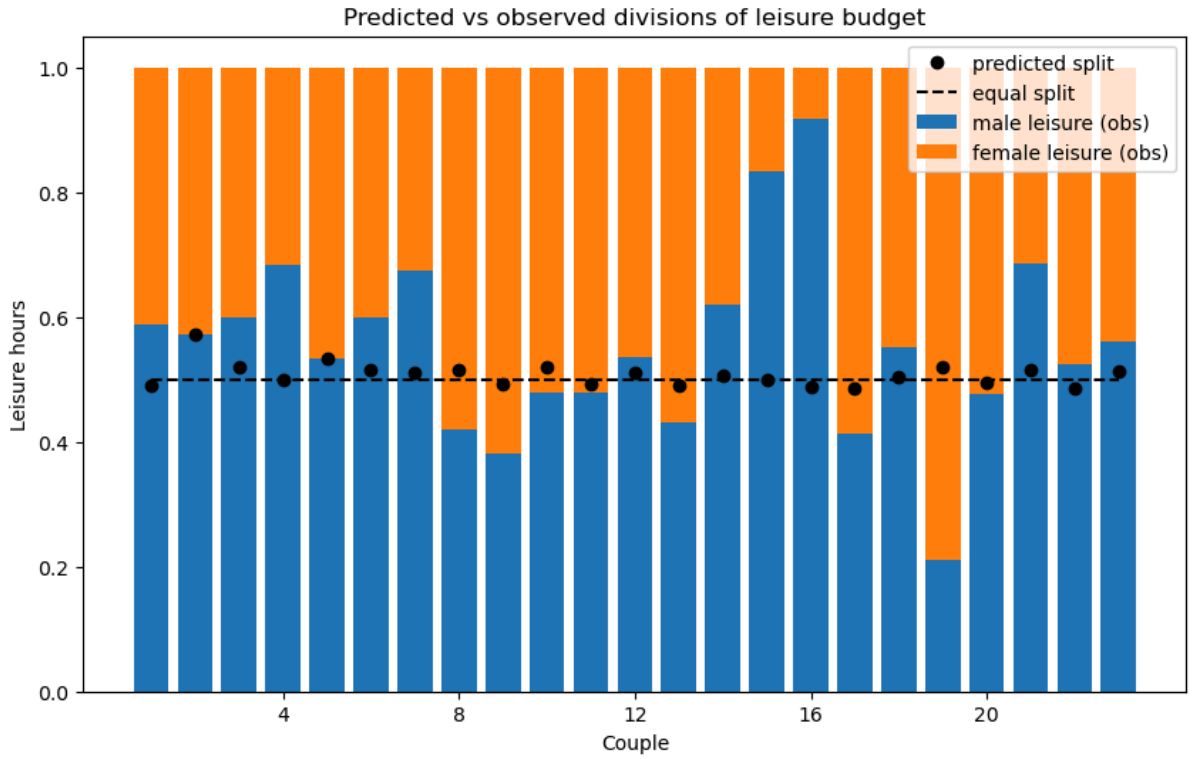


Fig 1: Stacked bar chart showing predicted split of household budget of leisure hours, the observed split, and additionally, the equal split, for each couple in the BaYaka.

In the Agta ($N_{household}$ = 55), we find intercept a ranging between -0.045 to -0.2, and slope b to be small and negative, with all points of highest likelihood below -0.0425 (refer to SI). This indicates that social capital slightly *disadvantages* people, such that when an individual's social capital increases by 1 z-score, their disagreement point *decreases* by 4.25%. We select the best fitting values (a = *-0.200*, b = *-0.05527*), and plug them into the deliberation dynamics to yield the leisure time split of each household (Fig 2). Similar to the BaYaka, the predictions suggest a nearly null effect of social capital on leisure time, with an average increase of 1 z-score social capital leading to 1.7% decrease in one's share of leisure time.

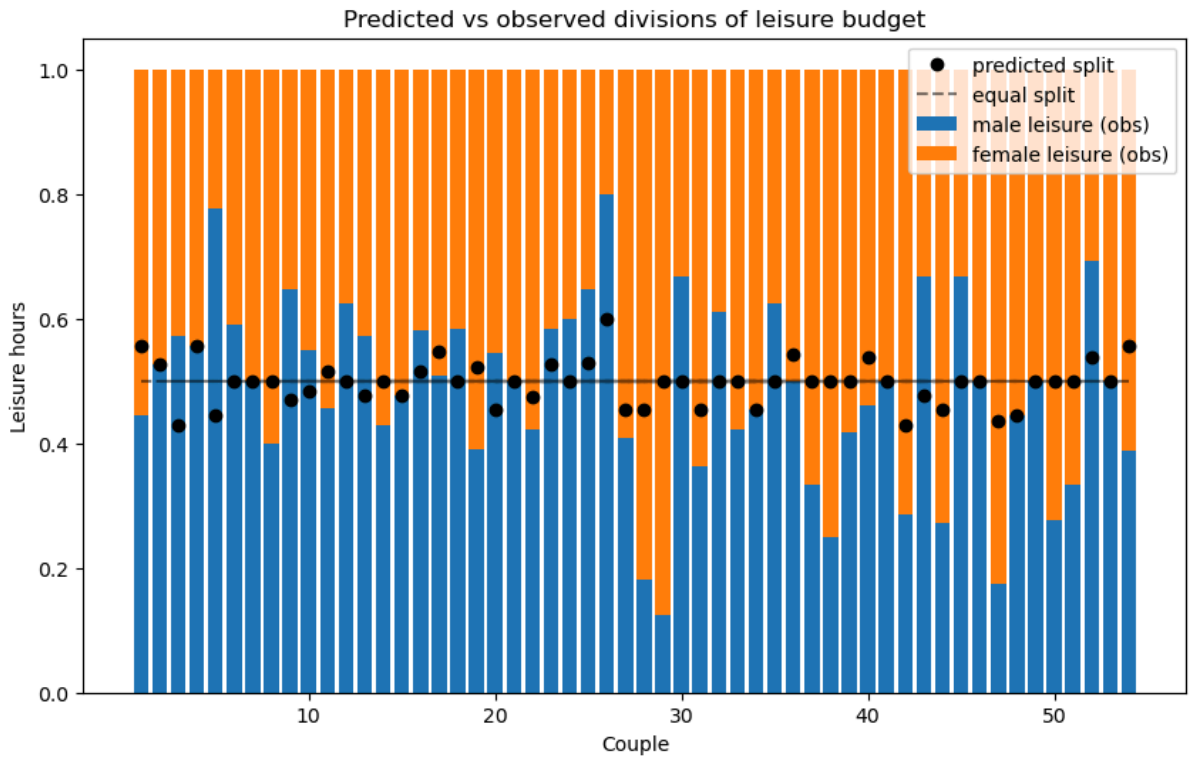


Fig 2: Stacked bar chart showing predicted split of household budget of leisure hours, the observed split, and the point for equal split of leisure hours, for each couple in the Agta

Overall, the generative model predictions align with our descriptive findings, both showing nearly equal division of leisure time across households. The generative model also shows that the effect of social capital on leisure time is non-linear i.e., not everyone gets the same boost in leisure time due to one additional z-score of social capital. It depends on how much their partner has and how much inequality there already is in the household. Inequality in leisure time generally exhibits diminishing returns; once the household is already very unequal, it takes a lot more shift in social capital to shift the leisure distribution. This is consistent with our following logistic regression model.

3.2. Bayesian Multilevel Logistic Regression

We fit a Bayesian multilevel logistic regression model on both datasets to understand the effects of within-household differences in social capital on the division of leisure time. We report the posterior

distribution over all parameters of the model (Tables 2, 3) and the logistic outcome distribution plots (Fig 3 & 4) using random draws from the posterior distribution.

In the BaYaka, the estimates show that differences in social capital have an overall small positive effect on leisure hours, with high uncertainty. Camps 2 and 3 show effectively null mean effects, while we see a small positive effect in camp 1. Overall, we find no support for our predictions

	Mean	**SD**	**HDI_2.5 %**	**HDI_97.5 %**
Social capital effect	0.061	0.436	-0.776	0.925
Camp-level variation in social capital effect	0.133	0.153	0	0.405
Intercept	-0.432	0.229	-0.899	0
Camp 1 social capital	0.077	0.077	-0.046	0.234
Camp 2 social capital	-0.006	0.061	-0.137	0.121
Camp 3 social capital	-0.029	0.081	-0.217	0.123
Average age	0.016	0.007	0.002	0.029
Age difference	0.007	0.011	-0.015	0.029
Dependants	0.009	0.033	-0.057	0.073

Table 2: Posterior distribution values over modelled parameters for the BaYaka, including the mean, standard deviation and the high-density interval limits

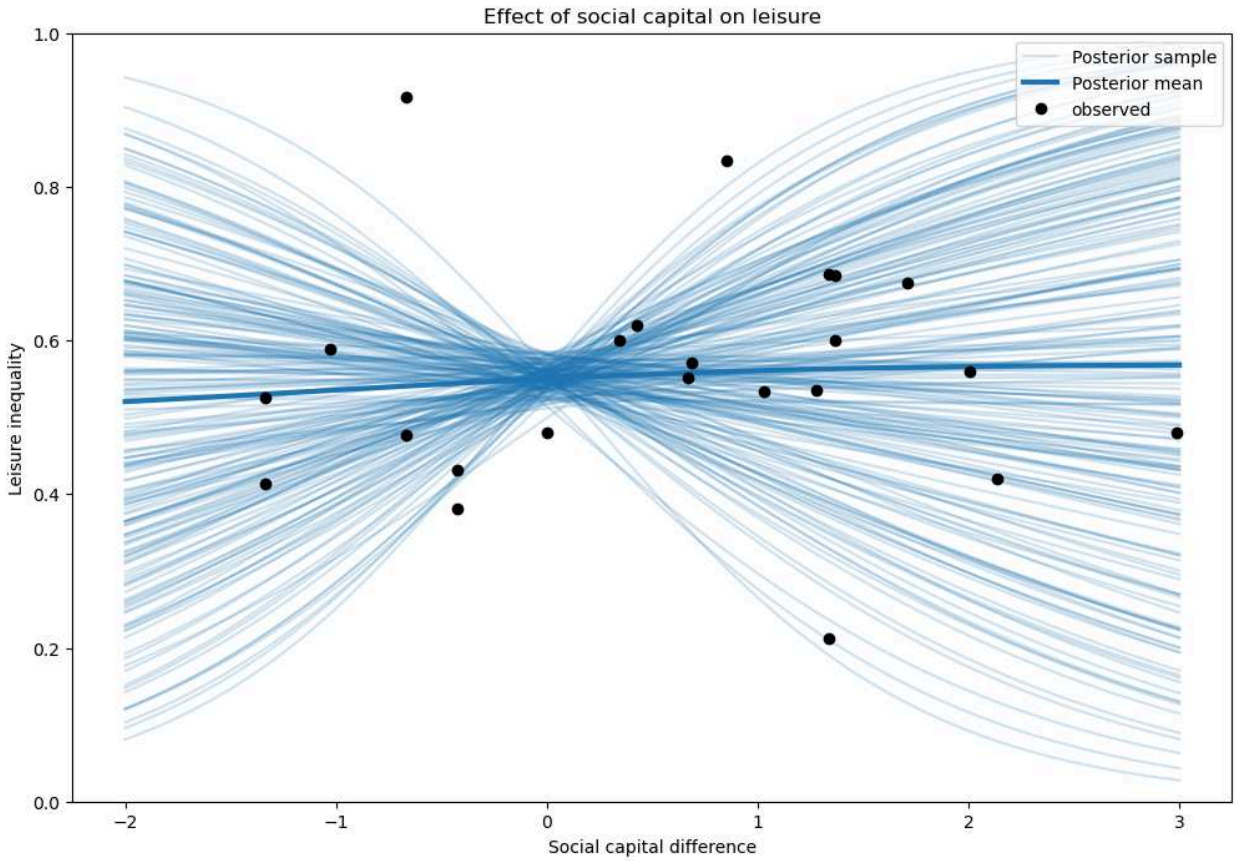


Fig 3: Outcome distribution plot over observed data from the BaYaka. Response variable (y) is male/ (male+female) leisure time, while the predictor variable (x) is the difference between the z-scores of partners' social capital (male-female). Transparent lines are 200 draws from the joint posterior distribution over all parameters.. We averaged the values of the control variables to allow plotting in 2 dimensions.

In the Agta, we find a slightly negative relationship between social capital and distribution of leisure hours from budget, corresponding to our generative estimates, but again with high uncertainty. The plot shows high variability in the division of leisure time, with a small negative trend. As with the BaYaka, we do not find strong support for our predictions.

	Mean	**SD**	**HDI_2.5%**	**HDI_97.5%**
Social capital effect	-0.182	0.399	-0.96	0.602
Camp-level variation in social capital effect	0.131	0.086	0.000	0.287

Intercept	0.0	0.161	-0.322	0.306
Camp 1 social capital	0.012	0.085	-1.68	0.185
Camp 2 social capital	0.029	0.067	-0.095	0.168
Camp 3 social capital	0.007	0.114	-0.237	0.235
Camp 4 social capital	-0.099	0.139	-0.415	0.125
Camp 5 social capital	-0.043	0.135	-0.324	0.225
Camp 6 social capital	-0.188	0.150	-0.491	0.033
Camp 7 social capital	-0.001	0.124	-0.247	0.267
Camp 8 social capital	-0.061	0.081	-0.231	0.082
Camp 9 social capital	-0.019	0.164	-0.347	0.327
Camp 10 social capital	0.039	0.107	-0.161	0.27
Average age	0	0.003	-0.007	0.007
Age difference	-0.001	0.013	-0.026	0.023

Table 3: Posterior distribution values over modelled parameters for the Agta, including the mean, standard deviation and the high-density interval limits

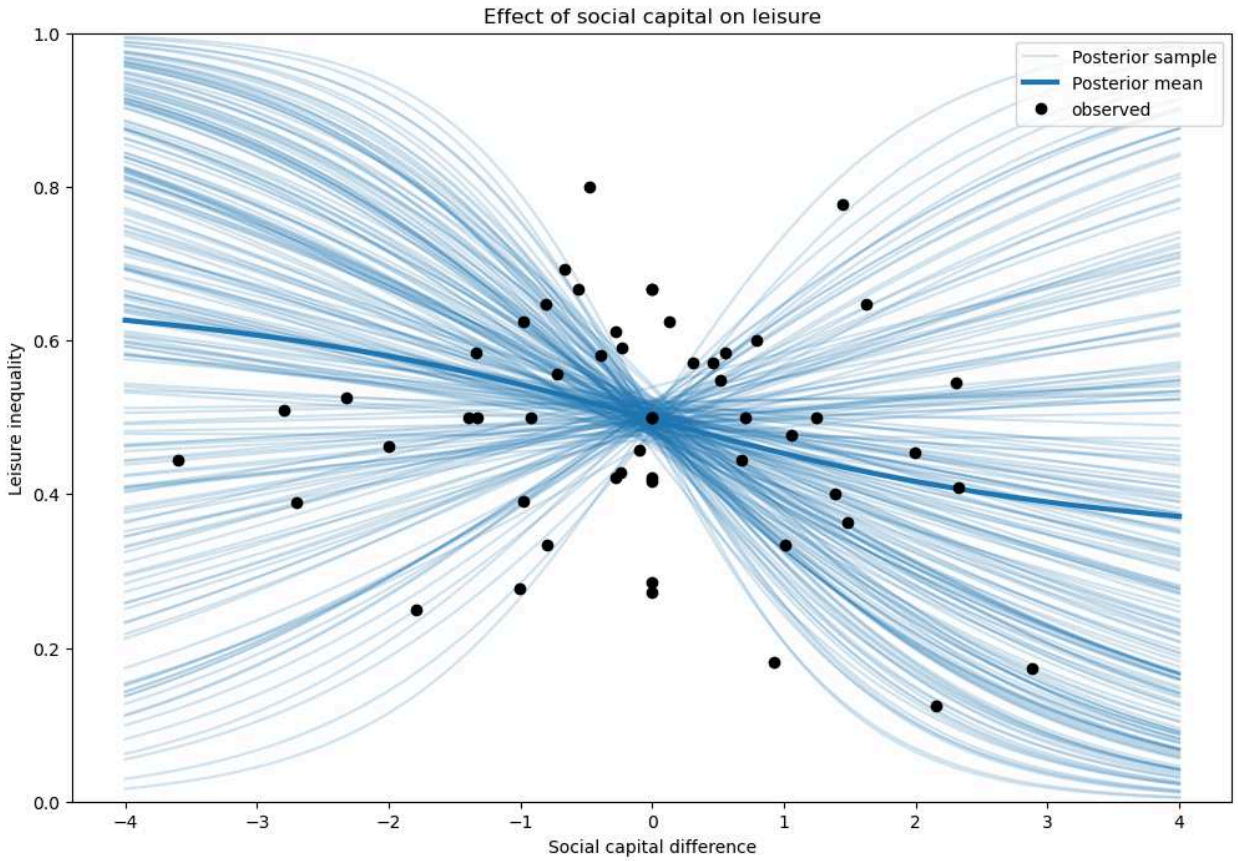


Fig 4: The response variable (y) is male/ (male+female) leisure time, while the predictor variable (x) is the difference between z-scores of partners' social capital (male-female). Transparent lines are 200 draws from the joint posterior distribution over all parameters. We averaged the values of the control variables to allow plotting in 2 dimensions.

Our additional measures of social capital, i.e., real-world food transfers in the BaYaka and campmate network data in the Agta, generally corroborate our above-mentioned results. Both show a similar lack of relationship with distribution of leisure hours from budget, and a close correspondence with measures from the HSGG and the Sharing Game (Fig 4; Fig 5). Both these measures, capturing a slightly different aspect of social capital than the HSGG and the Sharing Game, allow us to provide more robustness to the general finding that social capital does not translate to relative bargaining power, which can be translated into higher share of leisure in one's household. Moreover, their correspondence with the primary measures allow us to establish validity of the HSGG and the Sharing Game results.

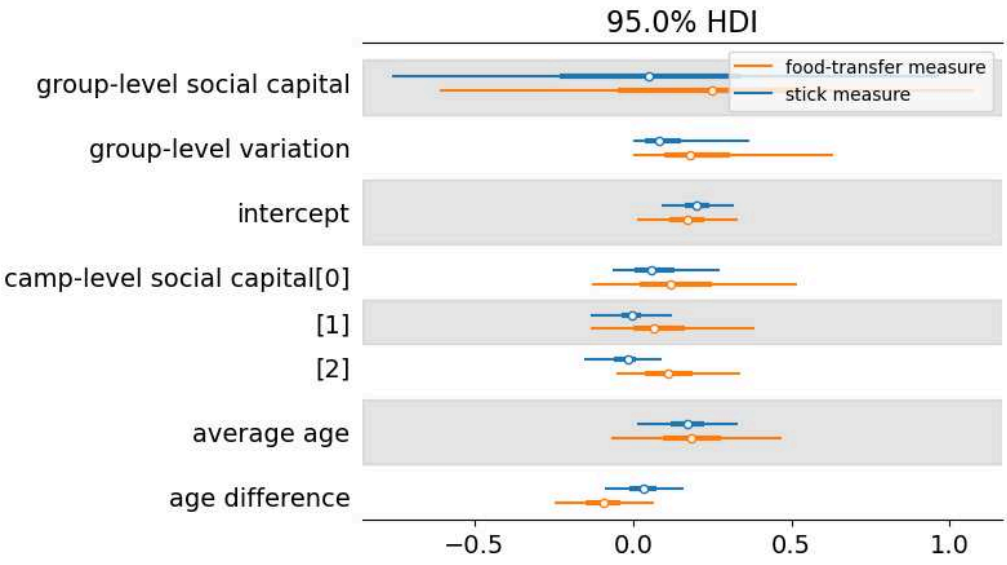


Fig 5: Forest plot for the BaYaka, showing correlation of real world food-transfer measures with division of leisure time from household budget. It overlaps with the primary measure of social capital, that is the honey-stick measure. Open circles represent the posterior mean, the thin line represents the 95% HDI and the thick line represents the central quartiles of the posterior

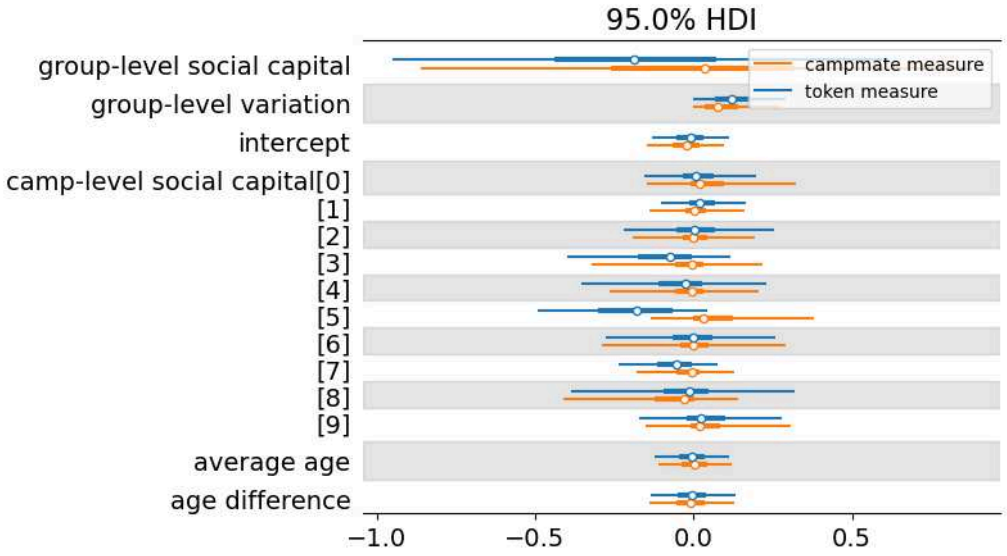


Fig 6: Forest plot for the Agta, showing correlation of campmate network measures with division of leisure time from household budget. It overlaps with the primary measure of social capital, that is rice tokens that each individual received. Open circles represent the posterior mean, the thin line represents the 95% HDI and the thick line represents the central quartiles of the posterior

4. Discussion

In both hunter-gatherer societies, our prediction that higher social capital gives bargaining power to individuals, who can then have a higher share of the household leisure budget, was not supported by our analysis of the data. The BaYaka shows a weak positive association, while the Agta shows a weak negative association, although both carry great uncertainty around the slopes and are consistent with a null association. We further corroborate these findings by using different measures of social capital for both the populations. Though the generative and Bayesian multilevel logistic regression approaches model the data using different tools and use quantitatively distinct estimates, they align over the finding that social capital does not provide significant advantage in bargaining for leisure time in these immediate-return hunter-gatherer populations. In fact, we find that there is remarkable equality in how males and females divide leisure time across households in both populations. This demonstrates an important finding, diverging from evidence from agricultural (Strassman, 2017) and industrialised societies (Hochschild & Machung, 2012; Nakamura & Akiyoshi, 2015; Voicu et al., 2009; Lachance-Grzela and Bouchard, 2010), as well as patrilocal populations (Chen et al ., 2023), where it is often the case that patriarchal norms are prevalent and gender inequalities thrive (Chen et al., 2023; Gupta & Stratton, 2008; Geist, 2005; Lennon & Rosenfield, 1994). Outside options have been seen to lead to inequalities within households in many large-scale societies (Shimray, 2004; Lennon & Rosenfield, 1994; Greenstein, 2000; Breen & Cooke, 2005); however our results of a null association between our measure of outside options and leisure time enjoyed, complimented by observed equal division of leisure in households, point to a potential role of some unique factors prevalent in these societies. We discuss the following considerations: a) bargaining does not take place as individuals follow norms, specifically norms of sex-egalitarianism and patterns of gendered DoL; or individuals do follow a bargaining process to inform their choices, but instead of social capital, b1) cultural norms of sex-egalitarianism determine what payoffs they can get from the bargaining process; and b2) demand sharing and bilocality shape the quality of one's outside options and provide leverage; or c) our experimental measure of social capital itself might be inadequate for capturing outside options;

a. First, we consider that bargaining itself might be overridden by other factors such as normative prescriptions of behaviour and non-substitutability of subsistence labour. Our own fieldwork as

well as other ethnographic studies have noted the fiercely egalitarian nature of these societies, where both males and females enjoy autonomy over their own activities, both hold equal political power in camp and decision-making power within households (Woodburn, 1982; Lewis, 2017; refer to section 2.1.1 and 2.2.2). The ethos of sex-egalitarianism is prevalent in everyday activities (Woodburn, 1982; Lewis, 2017; Townsend, 2018). It is often demonstrated in the nature of dance and music rituals, where males and females assert and counter-assert power over each other, ensuring that neither sex becomes dominant (Bombjaková, 2018; Knight et al., 2021). Same-sex coalitions are common, providing social support even to individuals with limited social capital and preventing exploitation by partners. Individuals who try to assert authority over others face open ridicule and are actively suppressed (Lewis, 2003; Lewis, 2015). We expected that individual autonomy would provide negotiation space for males and females. Instead, such enforced and pervasive norms of egalitarianism can itself shape behaviour, and suppress active bargaining between individuals. Additionally in many hunting-gathering populations, including the ones studied here, both males and females make vital contributions to the diet and often specialise (Gurven & Hill, 2009). Such specialisation and non-substitutability of labour can constrain bargaining as each partner would be required to do their own share, and cannot redistribute tasks, even if they have higher social capital and leverage.

b1. Second, we consider that sex-egalitarianism has an effect, not due to norm-following, but by shaping the payoffs individuals can expect to get from their social environments i.e., their outside options. For instance, in an egalitarian environment, if all individuals are expected to divide housework with their spouses in an equal manner, if hard work is seen as a virtue and those who try to exert authority over others or laze around are communally ridiculed, even individuals with higher social capital would have a preference for working hard and choosing equal division of labour. Within the scope of our model, this would mean including normative information in the form of priors, which will then shape the expected payoffs. Our bargaining model assumes that partners let their strategies be determined purely by their individual outside options; but if individuals come with prior cultural information about what options they could realistically have, this will modulate bargaining dynamics. Expectations of DoL arising from cultural norms of egalitarianism provide exactly such prior information. Our model also assumes that players value more leisure time over less. But, if a society develops egalitarian social norms and players internalise those norms into their utility function, they may actively desire equal distributions of

leisure. Amassing power over one's partner might be a source of shame or public sanction, which would generate a utility function inconsistent with the one used by the model.

b2. Other factors, such as bilocality and demand sharing, can also shape the outside options an individual has. Within the practice of bilocality, both males and females have decision-making power over the residence of a couple post-marriage, due to which both retain access to kin support in their adult lives (Dyble et al., 2015). This not only provides them social capital in the case of a failed marriage, but also precludes the emergence of strong lineage systems disadvantageous to either sex. Unlike large-scale societies (Borgerhoff Mulder, 2007), this can ensure that women are not suppressed living within a patrilineage. Many hunter-gatherer groups, including our study populations, also engage in a form of resource distribution called demand sharing, where individuals who need food or other resources can demand it from someone who has it and it is considered the possessor's duty to share (Lewis, 2017, Lewis et al, 2014; Smith et al., 2016; also refer to sections 2.1.1 & 2.1.2). This can provide individuals support outside of the household, removing the need to stick with an unfavourable distribution of labour. Individuals might share based on reciprocal relations or with kin, but need-based sharing dominates in resource transfers (Smith et al., 2019), leading to a low dependence on one's partner.

c. Finally, we consider the appropriateness of our measure of social capital, which differs from the conventional measures of outside options that consider economic resources of individuals, like employability, individual financial resources, control over production and relative resources (Alesina et al., 2013; Abraham et al., 2010; Fengdan et al., 2016; Diefenbach, 2002). Given the lack of material storage and resource accumulation in our study populations, social capital has been purported to be one of the more important measures of wealth in these otherwise egalitarian and non-hierarchical societies (Borgerhoff Mulder et al., 2009). The experimental measure of social capital has been seen to be associated with food security (Chaudhary et al., 2016), access to more mates (Chaudhary et al., 2015), and is partially heritable (Chaudhary et al., 2016). Additionally, we find the experimental measures to corroborate closely with real world observational measures of social capital, such as food transfers in the BaYaka and preferences for living with a campmate and sharing resources in the Agta. Thus, we believe we are well-motivated in considering this experimental measure. However, we suggest future exploration of other measures, such as embodied wealth measures (see Borgerhoff Mulder et al., 2009), or

domain-specific measures such as romantic partner desirability (Conroy-Beam et al., 2023), both of which cannot be tapped into by sharing tasks. We note that our study suffers from having a small sample size, which is a result of the small sizes of these camps of immediate-return hunter-gatherers. We address this by using Bayesian modelling which is robust to small samples.

Though we find no evidence for our primary prediction of social capital-mediated bargaining, the finding of equality in division of leisure time in households is interesting. It is well-known that human social life in populations without agriculture can be significantly different (Draper, 1975). Large-scale agriculture and sedentarization that began in the Holocene (Richerson et al., 2001) brought about drastic changes in patterns of subsistence, corresponding division of labour, gender roles and customs (Draper, 1975; Kent, 1995). Agricultural societies have now been known to have significantly more material wealth and political inequalities than their hunter-gatherer counterparts (Borgerhoff Mulder et al., 2009; Walker & Bailey, 2014), and are generally a lot more patriarchal (Kent, 1995; Fandrych, 2012), though not necessarily (Singh & Glowacki, 2022). Such documented equality in hunter-gatherers not only provides insights into how males and females cooperate with one another in this distinct socio-ecological environment, but also highlights social norms and practices which can avoid the emergence of inequalities. Minimal models are replete in the game theoretic literature, which aim to find elegant solutions to the problem of human cooperation. O'Connor, for instance, argues that extremely minimal conditions - a need for coordination, and social categories providing salient cues for this coordination - are sufficient for generating systematic inequality (O'Connor, 2019). A problem with this approach is that such minimal assumptions are in fact, not really minimal - they assume a lot about what is *not happening*. Posing minimal models side-by-side with complex descriptions can be methodologically valuable, and further question the supposed 'universality' of these models.

Households are the basic unit of human social life and how pairbonds come to cooperate with each other, reflects not only individual household dynamics but gender relations within the population. In this study, we explored the socio-cognitive process of bargaining as the mechanism shaping this DoL. A foray into the effects of social norms and conventions — even an incorporation of normative constraints into classical models of bargaining — is now warranted. We suggest that social prescriptions of gender can affect individual bargaining dynamics, shape the balance between cooperative and competitive interests of pair bonds, and ultimately give rise to cross-cultural differences in gendered divisions of household labour.

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