

Research



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# Gender disparities in material and educational resources differ by kinship system

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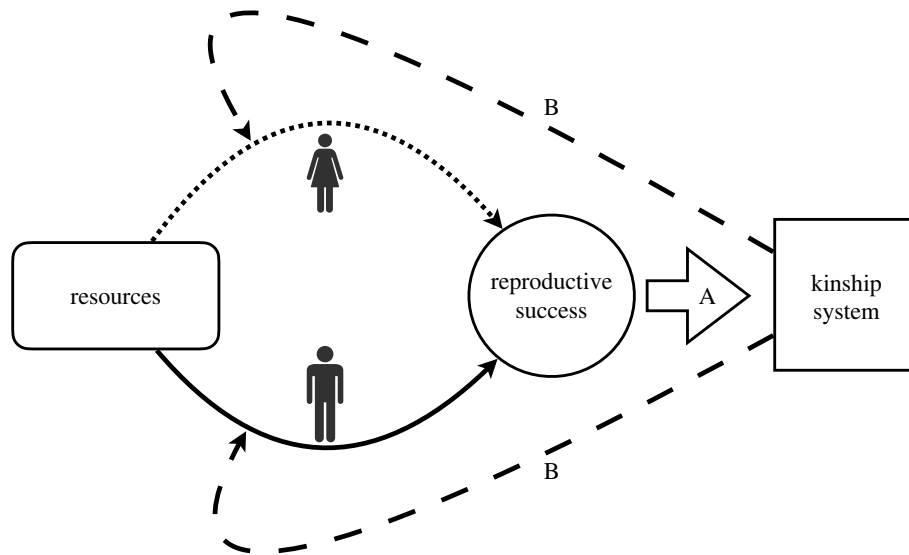
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Contemporary inequality exists at an unprecedented scale. Social scientists have emphasized the role played by material wealth in driving its escalation. Evolutionary anthropologists understand the drive to accumulate material wealth as one that is coupled ultimately to increasing reproductive success. Owing to biological caps on reproduction for women, the efficiency of this conversion can differ by gender, with implications for understanding the evolution of gender disparities in resource accumulation. Efficiency also differs according to the type of resources used to support reproductive success. In this paper, we review evolutionary explanations of gender disparities in resources and investigate empirical evidence to support or refute those explanations among matrilineal and patrilineal subpopulations of ethnic Chinese Mosuo, who share an ethnolinguistic identity, but differ strikingly in terms of institutions and norms surrounding kinship and gender. We find that gender differentially predicts income and educational attainment. Men were more likely to report income than women; amounts earned were higher for men overall, but the difference between men and women was minimal under matriliney. Men reported higher levels of educational attainment than women, unexpectedly more so in matrilineal contexts. The results reveal nuances in how biology and cultural institutions affect gender disparities in wealth.

This article is part of the theme issue 'Evolutionary ecology of inequality'.

## 1. Introduction

Ever since Darwin, evolutionary frameworks have been based on the premise that individuals compete over the resources that support their descendants. Because individuals vary in their ability to do so, inequality would seem inevitable; to some extent, this appears to be borne out: all societies express some degree of inequality in relation to individual characteristics such as age and gender [1]; neither are possessions and income distributed entirely evenly (e.g. [2]). Yet, the extent of inequality differs markedly across individual attributes, space and time, and numerous hypotheses have striven to explain variation in wealth [3–5]. Material factors as well as societal norms and institutions clearly play roles in the patterning of wealth inequality [3] and the potential for mitigating inequality via cooperation and redistributive norms [6–9]. Indeed, evolutionary explanations that join these disparate factors under a common framework have shed significant light on how and why



**Figure 1.** Conceptual model. Resources are used to support reproductive success. The ways that men and women do this can be highly divergent or more similar, according to the type of resource and surrounding socio-ecological constraints on reproduction. The relationship between resources and reproductive success (as well as other variables, such as paternity certainty) are thought to underlie differences in kinship systems (path A). Resultant norms and institutions can, in turn, influence the relationships between resources and reproductive success and feed potential divergence between men and women (path B).

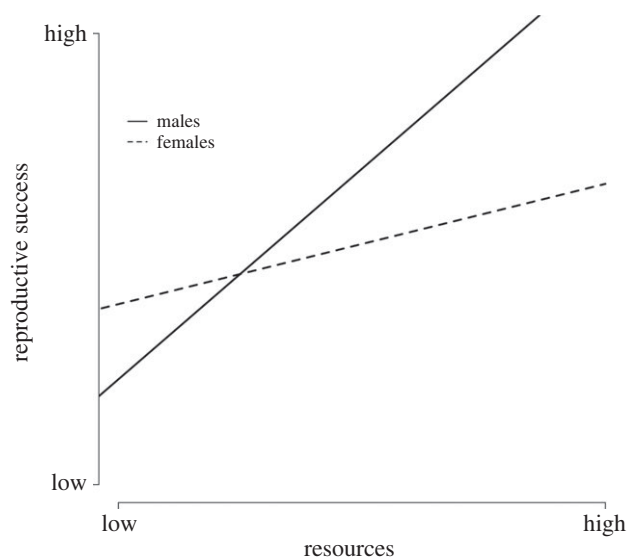
inequality varies over time and space [10,11]. In this paper, we link evolutionary models of resource inequality to sexual selection theory to investigate gendered inequality in two different types of resources. We ask whether gendered inequality in different resources—one material and one educational—is expressed differently in female- versus male-biased kinship systems that have historically relied on different resource bases.

To guide the reader through our framework (figure 1), we begin with the premise that different forms of resources are more or less easily converted to reproductive success. This, in turn, creates different motivations for individuals to compete over resources: resources with the highest efficiencies of conversion to reproductive success should be subject to greater competition and generate higher potential for resource inequality, all else equal. Next, we pick up arguments from sexual selection theory, including: the premise that (generally, if not always) males can achieve higher reproductive returns through resource accumulation than can females, resulting in higher variation in reproductive success (i.e. reproductive skew) in men than women; and therefore that gendered inequalities in resource acquisition should be more likely when (i) resources (i.e. material relative to embodied) can be used more easily by high-echelon men to accrue reproductive success, and (ii) social contexts (e.g. patrilineal versus matrilineal) place fewer constraints on men's ability to pursue divergent reproductive agendas.

To begin, we extend logic from the Santa Fe Institute's wealth inequality project and related arguments [10–13] to link differences in resources to the potential for resource inequality. Those arguments categorize 'wealth'<sup>1</sup> as existing in three broad classes. Material resources, including assets, durable goods, cash and income, are straightforward to quantify, acquire, control, and transmit, and grow more readily than other forms of resources. The potential for growth compounds differences between haves and have-nots; inheritance of circumscribed, economically defensible material resources further maintains differentials across generations. Material resources are correspondingly distributed highly unequally across societies [11]. They can support reproduction directly

[14] via mating and parenting effort, though the means by which women and men use material resources to support reproduction are known to differ [15–17]. 'Embodied' capital, including resources found in the body and mind [18], expresses relatively muted inequalities across small-scale societies. It supports reproduction both directly (e.g. via use of energetic reserves to support pregnancy) and indirectly (e.g. use of education/noetic capital to secure high-income occupations, status or social relationships that, in turn, support material resource acquisition and reproductive success). Finally, social capital is associated with moderate levels of inequality in humans, and offers indirect, but important support for reproductive success, as allies perform numerous activities (e.g. defence, allocare, provisioning) that improve reproductive outcomes [19,20].

Second, we draw from sexual selection theory to consider how differences between women and men in how resources are used to support reproduction [21,22] may feed gendered inequalities in different types of resources. We note at the outset that many of the assumptions of sexual selection theory are not met universally across human societies ([19,20] see also [21]) and that socio-ecological constraints frequently limit divergence in female and male reproductive agendas. In its simplest version, sexual selection theory uses the differences in reproductive potential between females and males to understand sex differences in reproductive agendas. It relies on the premise that, owing to underlying differences in their biology, males minimally invest relatively little into reproduction, whereas female investment is, minimally, significantly higher. This biological discrepancy results in lower caps to reproduction for women than for men. This, in turn, affects how women and men convert resources—whether material, embodied (i.e. somatic and noetic/intellectual) or social [12]—to reproduction, as some men can, under favourable conditions, achieve steeper reproductive gains through resource accumulation than can women (figure 2; redrawn from [24]). This results in a number of hypothesized differences between women's and men's general behaviours, where women, on average, are anticipated to focus on securing resources that support relatively few children, whereas men are anticipated to be motivated more by the acquisition of



**Figure 2.** The relationship between resources and reproductive success often differs for men and women, with the rate of conversion being higher for men. It is a truism that, on average, men and women achieve the same reproductive success (every child has one mother and one father), but variation around that leads to individual differences that support different gender-biases in parental investment and social structure [23]. The left of the figure exemplifies conditions under which women may be expected to achieve higher reproductive success than men with available resources, which is thought to explain female-biased inheritance as daughters are a more secure investment under such circumstances.

reproductive partners ([25]; see [26] for a contrasting perspective). Furthermore, according to sexual selection theory, variance in male reproductive success is expected to be higher than female [22,27], with highly successful males out-competing more plentiful, less successful males, setting the stage for greater reproductive inequality (or skew) in men compared to women under relevant circumstances.

Importantly, although there is significant evidence supporting predictions drawn from sexual selection theory across human societies [28–30], socio-ecological environments and institutions have important effects on expressed differences between men and women [31–33]. For example, our research group has found gender ‘reversals’ in health outcomes, where measures of matrilineal women’s health were better than men’s [31]. We also found that women in matrilineal contexts reported more friends than men did, a reversal of anticipated gender patterns [29]. These results are in line with other studies of matrilineal Mosuo, including those reporting higher risk-taking among Mosuo women [34] and reversals in Mosuo women’s giving (less than expected, a ‘male’ pattern of giving) in dictator games [35]. Societal norms clearly structure the expression of gender differences in other contexts as well. For example, technologies, dogs or other socio-ecological factors that lower variance in success of hunting increase women’s participation in it among Agta [36] and Martu [37] foragers. Shodagor women in Bangladesh engage in higher variance economic pursuits than men, because broader societal norms prevent men from selling fish [38]. Changing conditions, such as decreasing visibility of status ranking and allowing winnings to be redistributed to team-mates or children, can increase women’s competitiveness in economic games [34–36,39–41].

Up to this point, we have argued that properties of resources affect the general scope for inequality and that gender may,

under some circumstances, mediate the relationship between resources and reproductive success. Now, we tie these insights together to understand how variation in socio-ecologies affects the scope for gendered inequalities in different types of resources.

Specifically, we posit that socio-ecological environments structure the relationships between resources and reproductive success for women and men in two ways: (i) resources themselves affect the potential for gender divergences in conversion rates, resulting in gender-biased inheritance systems (figure 1, path A); and (ii) resultant gender-biased kinship systems’ norms and institutions structure the gendered production and consumption patterns (figure 1, path B). Path A arises because forms of subsistence that are not particularly productive, such as horticulture, are neither strongly monopolizable (e.g. because they are labour- rather than land-limited) nor conducive to strong opportunities for family expansion (e.g. because they have limited potential for growth). Resources that are not productive or worth monopolizing result in men and women exhibiting similar relationships between resource accumulation and reproductive success [42,43]. Thus, relatively low-yielding horticulture is frequently associated with female-biased kinship systems, especially where paternity certainty is low and grandchildren through sons are less assured. (We follow [44] in our broad use of ‘female-biased’ to encompass kinship systems that are more strongly oriented around women than men, including ones that are, to some degree, matri-/uxori-local, -lineal or -focal; see [45] for a different perspective.) High-yielding agriculture and pastoralism are more frequently associated with male-biased kinship systems. Path B arises when broader socio-ecologies impose limits on gendered activities, for example, by rendering male income unstable [46] or difficult to accrue owing to wider societal gender norms [38]. In such cases, men can be considered relatively peripheral [47] and might encounter difficulties in exerting their own reproductive agendas [48], as they are relatively unreliable in the contributions they make to their households, destabilizing the basis for household authority.

According to this framework, matriliney is a system of kinship that is often found in resource-moderate ecologies—those in which resources are productive enough to require defence [49] but not productive enough to generate highly divergent reproductive returns between men and women. Indeed, material wealth intensification is thought to undermine matriliney [50–52], as it frequently allows some men to benefit more strongly from increased wealth via reproductive competition. For example, in polygynous horticultural societies that adopt cattle, men may use cattle for bridewealth [50], therefore achieving higher reproduction through the acquisition of new wives. Women in such scenarios have opportunities to compete reproductively, but the differences in women’s reproduction pale in comparison to those in men. By contrast, in resource-moderate environments we can expect the rates of reproductive returns to wealth for women and men to be relatively similar (i.e. the slopes in figure 2 would be statistically indistinguishable) [43,50]. If so, the scope for gender inequality in wealth may also be relatively limited [53].

To summarize, the resources that generate the highest potential for wealth inequality are also commonly those that create the greatest potential for divergence between men and women. Where resources are less easily monopolized and less productive, divergence between genders in terms of reproductive agendas and the resources that support

those should be minimal; gendered inequality is most likely in socio-ecological systems that allow some men to achieve very high reproductive success at the expense of other men. In other words, differences in production give rise to gender-biased kinship systems, with varying levels of differentiation between women and men. Broader social norms (e.g. monogamy [54], religious strictures [55]) can place additional constraints on gendered reproduction that affect the scope for gendered inequality. In this paper, we extend prior work [56] developing related arguments to posit that:

- (i) gender inequalities in resource accumulation are more likely in patrilineal than matrilineal contexts [53]; and
- (ii) material resources (income) are likely to diverge more strongly between genders than other forms of resources (such as education).

We focus here on a single form of material resources (individual income) and one form of embodied wealth (education), as we do not have adequate measures of social capital in the data available to us, or to asset-based measures of wealth at the individual level. We investigate the extent to which gender predicts acquisition of these forms of wealth among matrilineal and patrilineal populations of ethnic Mosuo residing in southwestern China. Our analysis offers some preliminary insights about the connections between wealth, gender, inequality and broader social systems, which we hope will inspire future research on this topic among human behavioural ecologists and evolutionary demographers [57,58].

### (a) Population

Our data were collected among Mosuo participants residing in southwestern China on the border of Yunnan and Sichuan Provinces. Mosuo are well known to anthropologists for being one of China's only matrilineal societies [59,60]. In their matrilineal communities, Mosuo traditionally reckon descent and pass inheritance along female lines [61,62], whereby everyone residing in a household stands to inherit its resources, but, because children typically reside with their mothers and their mother's brothers rather than their with their fathers, inheritance effectively proceeds through daughters [43]. Residence is duo/natalocal [63]: women and men remain in their natal households throughout their lifetimes. Women and men normatively engage in non-marital, but often enduring partnerships [52] known as *tisese* or *sese* [64], in which a man visits his partner in her natal home at night, but remains a resident of his own natal home. Mosuo society is multi-level, with decision-making occurring among individuals, sometimes in coordination with a reproductive partner [65] or sibling [62], within households, and in broader corporate descent groups, though the latter were probably of greater importance historically than they are today. Anecdotally, individually earned incomes are easier to control than resources that are produced by joint efforts of household members. We are not aware of studies that systematically investigate what women and men do with resources they control, but anecdotally it appears commonplace for men to divert resources more towards leisure activities and mating pursuits and for women to channel resources into their households [59]. Reproductive decisions are made by individuals, albeit commonly influenced by others, and are said to be freer than in

many parts of the world where reproductive unions are affairs of the broader family (but see [66]).

Less well known to anthropologists are subpopulations of Mosuo who normatively practice patrilineal descent and inheritance [63,67,68]. In these communities, which are geographically close to, but separate from, matrilineal communities, families often live within a stem family structure [69], in which a couple co-resides with (inheriting son) the husband's parents and the couple's children and wherein the main homestead is inherited by one son, typically the first- or last-born [68]. Marriage is normative, nominally exclusive, and typically conducted by bringing a woman to reside in her husband's house (i.e. *viril/patrilocal* [45]). Fertility is slightly higher than among matrilineal Mosuo [56], but low, overall, even outside the context of the Chinese fertility policy that has limited ethnic minority individuals to two or three children for several decades [70]. Reproductive and resource-based decision-making operate at multiple levels among patrilineal Mosuo, as well. There is arguably less individual autonomy given the stem family structure that is prevalent in patrilineal areas, though the relatively recent cleavage from matrilineal subpopulations has created greater cultural proximity among patrilineal and matrilineal Mosuo relative to other patrilineal minorities to whom Mosuo are commonly compared [63,67,68].

The socio-ecologies that matrilineal and patrilineal Mosuo inhabit are distinct in a number of ways that are at least partially consistent with evolutionary explanations [68]. Matrilineal Mosuo reside at relatively high altitudes [71] in the Hengduan mountains in relatively expansive, flat basins that produce one major harvest a year of crops including corn, buckwheat and rice, and produce garden vegetables at multiple times across the year. Productivity is limited more by labour than by land and portions of plots routinely lie fallow. Livestock are integral to household consumption and Mosuo rely especially on pigs and fowl. Unlike many matrilineal populations [50,51], Mosuo keep cattle. These are tended collectively by several adults who sit together while cattle graze. Compared to matrilineal Mosuo, patrilineal Mosuo live in more difficult terrain. Although at lower altitude, their environments are much steeper, making travel between households difficult and land considerably more circumscribed. They experience two harvests per year and a warmer climate, on average. Livestock are important, although they are kept in lesser quantities than in matrilineal areas and there is a heavier reliance on sheep and goats than on cattle.

Market integration has changed Mosuo lifestyles in various ways in recent decades [72,73]. Matrilineal communities have been particularly affected by market integration [6], as the area's connections to regional markets have long been stronger than those of patrilineal communities. Tourism has also been a stronger influence on matrilineal economies, as tourists have flocked to witness (and sometimes participate in the 'women's kingdom' [74]), resulting in significantly higher wealth in matrilineal communities, higher emphasis on market-oriented lifestyles, and higher levels of inequality overall compared with patrilineal communities [6]. At the same time, matrilineal Mosuo have a number of redistributive norms that buffer somewhat against the hypothesized effects of material wealth on escalating inequality [6], including relatively gender-egalitarian or slight daughter-biased ethos [56]. Previously, we anticipated that some of these

values would transition under the forces of markets and acculturation to approximate majority Han patrilineal values [52], but our recent evidence, both qualitative and quantitative, has failed to support that speculation, finding that at least some matrilineal norms and institutions are robust despite posited external pressures that might erode them.

## 2. Methods

We collected data via a sociodemographic survey conducted with 505 households over seven months in 2017. This included 15 Mosuo villages—six matrilineal villages and nine smaller patrilineal villages. C.-Y.S., accompanied by a local research assistant, travelled house-to-house in these villages and invited a primary adult respondent in each house to supply information on household composition and wealth. We asked the respondent to provide sociodemographic information for all members of the household, including marital status, reproductive history, occupation, income and educational attainment. Each interview lasted approximately 30–90 min. Interviews were primarily conducted in Mandarin Chinese, and the research assistant occasionally translated responses from Naru (the Mosuo language) and the local Chinese dialect.

University of New Mexico's IRB provided ethical oversight for the associated data collection (06915) with additional ethical review by Fudan University (16268).

### (a) Analysis

All data treatment and analysis were performed in R 4.1.2 [75]. We merged and cleaned datasets drawn from individuals and households and recoded and created variables of interest in preparation for analysis using base R and the dplyr package [76]. From the larger dataset, we selected only adults (greater than 16 years old) of known age and gender living in either patrilineal or matrilineal villages ( $n = 2296$ ). When creating subsets of these data for separate analyses, we selected only complete cases that did not contain missing values in any variable of interest to a given model; missing data differ across models as a result. We collapsed categorical variables describing fluency in Mandarin Chinese (originally five levels) and educational attainment (originally nine levels) to three levels (none, some and fluent; none, midway through middle school, and high middle school or above), owing to low sample sizes in more finely resolved bins and for clarity in analysis and presentation. Similarly, we created four age cohorts from oldest (62 years old or more) to youngest (17–21 years old) in approximately 20-year intervals surrounding historical events in China (cohort 1 contained those born before 1955 during the pre-Communist era; cohort 2 contained those born between 1956 and 1975 during the high times of Maoism; cohort 3 contained those born between 1976 and 1995 under the influence of post-Mao economic reforms; and the youngest cohort from 1995 onwards captured those born in the recent more globalized era).

Our statistical models present predictors of two outcomes related to material and educational resources. Individual access to material resources was modelled using reported monthly income data based on the prior month. We recognize that income represents a flow of material resources rather than a stock, potentially affecting its conversion rate to reproductive success, if, for example, it were consumed rather than accumulated or channelled towards reproductive effort. However, we have shown previously that income is positively associated with modern asset wealth [6] in this population. We discuss this potential limitation below, but generally do not feel it is likely to invalidate the conceptual framework followed here. Because a large percentage of individuals (46.8%) reported no income, we

used hurdle lognormal models to estimate the effects of our predictors on income. Hurdle lognormal models contain two parts: a binomial logistic regression modelling the probability of the data being 0 and a lognormal regression modelling the data conditional on it being greater than zero [77,78]. Hurdle lognormal models are frequently used to model wealth or income data and have been shown to be more robust than the truncated normal (Tobit) model [79]. Hurdle lognormal models were fit with the GLMMadaptive package, which also allowed us to fit random intercepts for each household to account for possible dependence of data-points at the household level. The hurdle model required small coefficients in its calculations, so we transformed the age variable by dividing by 10 and the age squared variable by 1000 to meet these requirements. For clarity in presenting plots of model effects, we transformed the estimates from the binomial portion of the hurdle model to reflect the likelihood of having an income greater than zero (instead of having an income equal to zero) by multiplying the coefficients by  $-1$ .

Educational resources were represented by an individual's educational attainment (an ordinal variable ranging from 0 for no education to 2 for high education). We modelled this outcome using ordinal logistic regressions from the MASS [80] and ordinal [81] packages.

In constructing full regression models for model comparison [82], we included those variables and interaction terms we considered most salient for a given outcome. In modelling income, we included as predictors age, gender, kinship system, level of fluency in Mandarin, education level and parents' level of fluency in Mandarin, as well as interactions between gender and kinship system. We added  $\text{age}^2$  to the predictor variables in the income model to allow for nonlinear effects of age on income. Predictor variables for educational attainment included age cohort, gender, prevailing kinship system, parents' Mandarin fluency, and the interaction between gender and kinship system. For both the hurdle lognormal and ordinal logistic models, we included random intercept terms for the household to account for the non-independence of individuals from the same household.

We selected models and parameters using forward, backward and bi-directional stepwise selection processes via R's step function [80] and comparisons of Akaike information criterion [82,83] and variance inflation factor [84] criteria calculated by the car and stats packages. We calculated robust standard errors for candidate regression models in the lmtest and jtools [85] packages and created figures using the ggplot2 [86] package. Finally, we employed the ggeffects package [87] to present marginal effects and interactions on model outcomes.

## 3. Results

Summary statistics for the sample are presented in table 1. The dataset included 2386 individuals comprising 1212 women and 1174 men. Matrilineal villages housed 769 women and 737 men (1506 total); 443 women and 437 men resided in the patrilineal area (880 total). Ages of individuals in the sample ranged from 17 to 94 years old with a mean of 42.4 years old. Material resource measures favoured men, with 51% of men versus 27% of women ( $\Delta 24\%$ ;  $n = 1204$ ) reporting incomes greater than 0 in matrilineal areas and 59% versus 25% ( $\Delta 34\%$ ;  $n = 831$ ) reporting incomes in patrilineal areas. Mean monthly income was 15% lower in the patrilineal area when including all individuals who reported incomes of 0 or above ( $n = 2032$ ), with women making 47% less than men in the matrilineal areas and 67% less in the patrilineal areas. When we examined these measures only for those reporting income greater than zero ( $n = 801$ ), individuals showed a 21% lower overall mean income in

**Table 1.** Summary statistics for educational attainment, Mandarin fluency, age and monthly income.

	matriliny			patriliny			whole sample
	F	M	mat. total	F	M	pat. total	
	769	737		443	437		2386
educational attainment							
none	338	146	484	210	101	311	795
medium	287	393	680	137	255	392	1072
high	132	176	308	89	80	169	477
Mandarin fluency							
none	20	8	28	44	18	62	90
some	274	150	424	197	121	318	742
fluent	467	570	1037	199	298	497	1534
parents' Mandarin fluency							
none	25	22	47	16	33	49	96
some	234	237	471	84	153	237	708
fluent	160	189	349	64	83	147	496
cohorts							
62–94 years old (1)	119	88	207	73	47	120	327
42–61 years old (2)	261	254	515	157	154	311	826
22–41 years old (3)	336	328	664	178	193	371	1035
17–22 years old (4)	53	67	120	35	43	78	198
age (years) $n = 2386$							
range	17–94	17–91	17–94	17–92	17–88	17–92	17–94
mean	43.85	41.37	42.64	42.94	40.86	41.91	42.4
individual income presence							
yes	176	283	459	105	240	345	804
no	468	277	745	322	164	486	1231
monthly income (CNY) $n = 2032^a$							
range	0–10 000	0–10 000	0–10 000	0–10 000	0–10 000	0–10 000	0–10 000
mean	761	1443	1078	462	1398	916	1012
monthly reported income > 0 (CNY) $n = 801^b$							
range	20–10 000	40–10 000	20–10 000	40–10 000	45–10 000	40–10 000	20–10 000
mean	2784	2865	2834	1879	2357	2211	2566

<sup>a</sup>Individuals who provided a numeric income greater than or equal to 0 excepting three with reported monthly incomes over 30 000 CNY.

<sup>b</sup>Individuals who reported an income greater than 0 excepting three with reported monthly incomes over 30 000 CNY.

the patrilineal areas with women earning 20% less than men, but near equity (a 2.8% difference) between the genders in the matrilineal area.

Measures of educational resources generally demonstrated male bias in both matrilineal and patrilineal contexts. Of the 2344 individuals for whom there were data on educational attainment, 1472 resided in the matrilineal area and 872 in the patrilineal. In both areas, men displayed similar degrees of higher educational attainment (represented by medium and high levels) than women, with matrilineal individuals displaying slightly higher levels of education overall (80% men versus 55% women;  $\Delta 25\%$  in the matrilineal area and 77% men versus 52% women;  $\Delta 25\%$  in the patrilineal area). Differences between men's and women's fluency in Mandarin

(i.e. reported as fluent) were apparent in the matrilineal area (78% for men versus 61% for women;  $\Delta 17\%$ ;  $n = 1489$ ) and slightly more pronounced under patrilineal (68% for men versus 45% for women;  $\Delta 23\%$ ;  $n = 877$ ).

Models (tables 2–4; figure 3) demonstrated strong relationships between many of our variables of interest and material and educational resources outcomes. Guided by our model selection process, we first investigated whether gender, age, fluency in Mandarin, educational attainment, and interactions with gender and other variables were significant predictors of an individual reporting an income, and whether those relationships differed in matrilineal and patrilineal contexts. Odds ratios (OR) derived from marginal coefficients of the zero part of the hurdle model showed

**Table 2.** Marginal coefficients of hurdle-lognormal income model (reporting any income).

	estimate	robust s.e.	z-value	p	OR
male <sup>a</sup>	1.09	0.406	2.69	<0.01	2.98
patrilineal	-0.282	0.211	-1.34	0.181	0.755
age/10	5.47	1.85	2.96	<0.01	238
age <sup>2</sup> /1000	-7.36	2.48	-2.97	<0.01	0.001
fluent in Mandarin <sup>b</sup>	2.23	0.739	3.02	<0.01	9.32
medium ed. level <sup>c</sup>	0.643	0.293	2.19	0.028	1.90
high ed. level	0.458	0.282	1.63	0.104	1.58
male × patrilineal	0.926	0.405	2.29	0.022	2.52

<sup>a</sup>Female.<sup>b</sup>Some Mandarin.<sup>c</sup>No education.**Table 3.** Log-linear component of hurdle-lognormal income model (roughly, income).

	beta	robust s.e.	z	p-value
male <sup>a</sup>	0.030	0.083	0.359	0.720
patrilineal	-0.155	0.124	-1.246	0.213
age/10	1.068	0.247	4.324	< 0.01
age <sup>2</sup> /1000	-1.581	0.338	-4.673	< 0.01
fluent in Mandarin <sup>b</sup>	0.346	0.138	2.515	0.012
medium ed. level <sup>c</sup>	0.109	0.126	0.860	0.390
high ed. level	0.374	0.143	2.614	< 0.01
male × patrilineal	0.081	0.149	0.544	0.586

<sup>a</sup>Female.<sup>b</sup>Some Mandarin.<sup>c</sup>No education.

that being male (OR = 2.98) and having fluency in Mandarin (OR = 9.32) increased the likelihood of reporting an income (table 2; figures 3*a* and 4). Owing to the quadratic term, the relationship between income and age was nonlinear: when controlling for other terms we observed that the likelihood of having an income peaks in the late 30s or early 40s (figure 4). Controlling for age, fluency in Mandarin, and education levels, we found that the influence of being male on reporting any income was reduced in matrilineal, meaning that men and women were similarly likely to report income, all else equal, under matrilineal.

The log-linear portion of the income hurdle model (table 3 and figure 3*b*) demonstrated significant relationships between income and age, fluency in Mandarin and high educational attainment. Plots of these variables illustrate that men were more likely to report income across all ages, but this was more pronounced in patrilineal (figure 5). Higher education had a clear positive effect on income in both the matrilineal and patrilineal areas and was more concentrated in younger individuals, as expected.

Stepwise selection for an ordinal logistic regression model for educational attainment chose gender, kinship system, parents' level of Mandarin fluency, age cohort and the gender × kinship interaction terms to remain in the best fitting model. When these parameters were used in a cumulative link mixed model with household as a random effect, odds ratios demonstrated positive effects on educational attainment for being male (OR = 2.10), living in the patrilineal area (OR = 2.07), having a parent fluent in Mandarin (OR = 5.76) and being in the youngest age cohort (OR = 11.9; table 4 and figure 3*c*). The interaction term on gender and kinship system was negative, opposite to what we expected, indicating that being a man in matrilineal led to higher odds of attaining higher education relative to patrilineal. When holding all factors but gender and kinship system constant, women in the matrilineal area appeared more likely to report no education and comparatively less likely to report higher education than women in the patrilineal area (probabilities of 53%, 44% and 2.7% versus 35%, 59% and 5.5% chances of being in the no, medium, or high education categories, respectively). Men in both the matrilineal and patrilineal areas demonstrated similar educational attainment probabilities (36%, 58% and 5.2% versus 38%, 57% and 4.8% chances of being in the no, medium or high education categories, respectively).

## 4. Discussion

This paper sought to investigate the extent to which matrilineal and patrilineal supported gender inequalities in various resources that, in our interpretation of sexual selection theory, should be more or less prone to gendered differentiation given differences in how men versus women translate resources to reproductive success. Specifically, we anticipated higher divergences in resource accumulation in patrilineal contexts compared to matrilineal ones. We speculated that differences might be easiest to detect for material resources (here, income) and relatively limited for embodied resources (here, education). Our investigations provide only partial support for these expectations: men were more likely to report earning an income; amounts earned were generally higher for men than for women; and educational attainment was higher for men than for women. The effect of being male on

**Table 4.** Ordinal regression for educational attainment.

	estimate	robust s.e.	t-value	p	OR
0 1	−0.446	0.821	−0.543	0.587	0.640
1 2	3.32	0.831	4.00	< 0.01	27.8
male <sup>a</sup>	0.741	0.155	4.77	< 0.01	2.10
patrilineal	0.728	0.222	3.28	< 0.01	2.07
parents some Mandarin	0.480	0.280	1.72	0.086	1.62
parent fluent in Mandarin <sup>b</sup>	1.75	0.313	5.60	< 0.01	5.76
42–61 years old <sup>c</sup>	−1.10	0.831	−1.33	0.184	0.332
22–41 years old	0.813	0.829	0.981	0.327	2.26
17–22 years old	2.48	0.850	2.92	0.004	11.9
male × patrilineal	−0.804	0.272	−2.96	0.003	0.448

<sup>a</sup>Female.<sup>b</sup>Parents speak no Mandarin.<sup>c</sup>Cohort 62 years old or older.

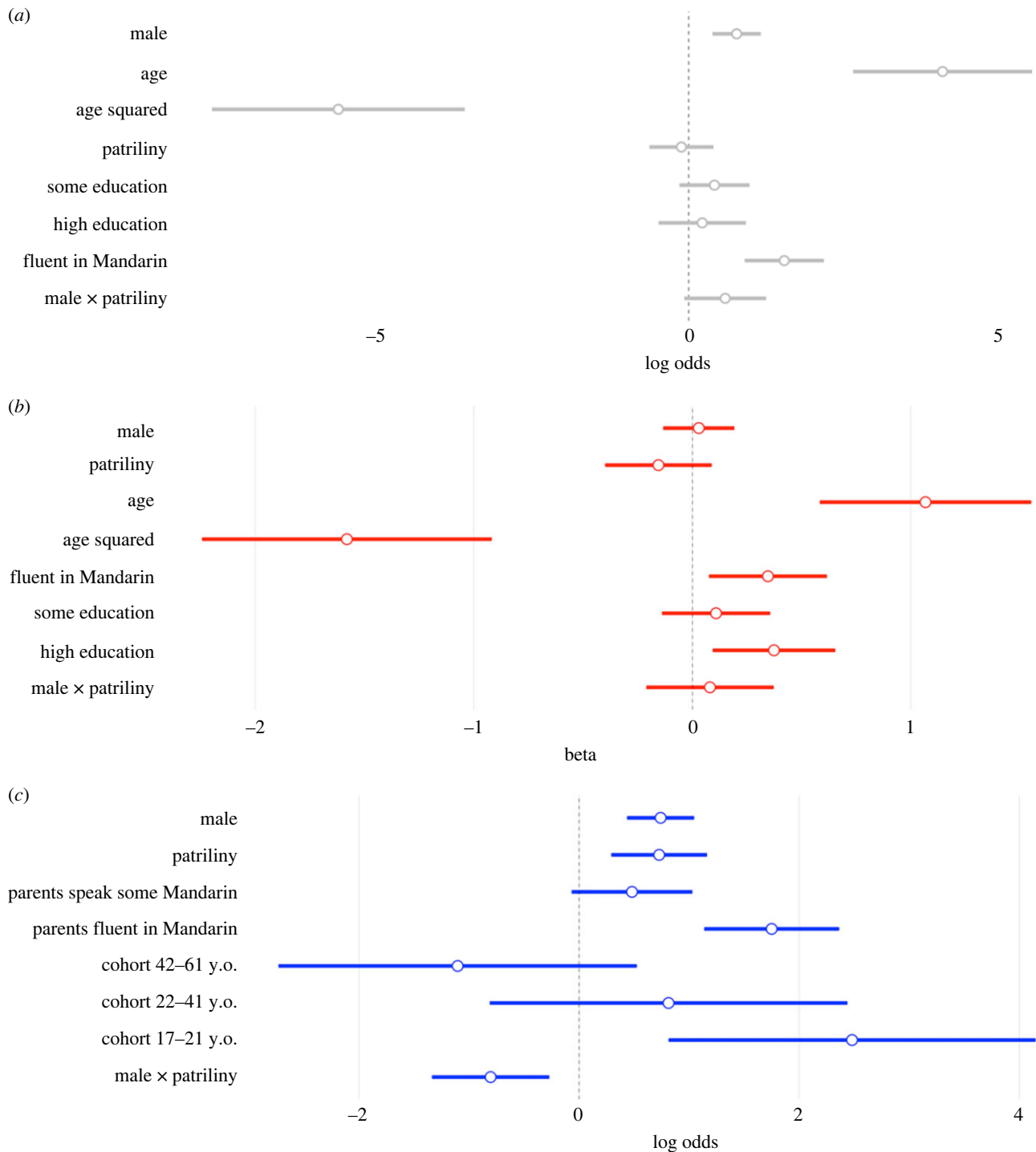
income was reduced by matrilineal context, as expected. Finally, men were more likely to achieve higher education than women in matrilineal contexts than they were in patrilineal ones, contradicting our expectations.

According to sexual selection theory, women and men often have different aims in the use of resources to support reproduction [24,25,88,89]. Most investigations of related ideas focus on how women and men translate the same resource (e.g. money, cattle) into reproductive success [43,50] and evidence in numerous contexts supports the idea that men and women use similar resources in different ways to support divergent reproductive agendas [15,17,21,48]. Yet, resources in their essence vary in the extent to which they can support reproduction: material resources such as cash and assets, especially monopolizable forms that are subject to economies of scale or compounding returns, provide a much stronger basis for large differences in wealth [3,90,91] and in reproductive success [11]. Embodied wealth, including differences in size and somatic resources, can also support large differentials between males and females [92,93], especially in species where reproduction is closely tied to genetic quality rather than wealth. Yet, in human societies that are tied to markets, and where markets for education remain loosely developed [8], variation in embodied resources is likely to be less influential or direct than material resources, as a means of accruing partners or enhancing child welfare. Our analysis has previously shown large differentials in household material wealth in both matrilineal and patrilineal contexts [6], especially in the forms of wealth that were critical to local forms of production (i.e. income for tourism-tied economies and farm assets for agricultural economies). Here, these inequalities seem to extend to differences based on gender, but only in part: gender differences in income were less in matrilineal contexts than patrilineal ones, but men reported higher incomes in both contexts. Contrary to expectations, men attained more education and more so in matrilineal contexts than patrilineal ones. We suspect that there are historical reasons for male-biased investment in education among even matrilineal Mosuo, including an association with religious structures that have long centered on men [94]. Specifically, prior to educational reforms of the Maoist era,

formal education arose either in association with Buddhism or Confucianism, largely excluding girls and women. Furthermore, if education serves as a means of acquiring market-based occupations structured by majority Han, patriarchal opportunity structures, then parents may benefit less from investing in daughters' education than in other forms of wealth such as social capital that help to secure more local opportunities that depend less on education [95]. Certainly, the analysis reinforces the need to separate educational capital from other forms of somatic capital in broader considerations of embodied resource differentials.

That differences between women and men were expressed differently in patrilineal and matrilineal contexts illustrates the potential importance of gender norms in laying out the landscape of gender-based opportunities. Historically, differences in the ecologies of patrilineal (mountainous and land-limited) and matrilineal (expansive and labour-limited) are likely to have driven differences between reproductive return rates, in turn, leading to relatively higher reproductive pay-offs for men in pursuits like education and material wealth acquisition. Now, patrilineal Mosuo are largely monogamous and also limited to a maximum of three children, which limits the potential extent of differences in reproductive variance between men and women [22] and, with it, any underlying 'biological' basis for greater investments in male capital. Furthermore, market integration, while more limited in the patrilineal context, should minimize subsistence-based differences between matrilineal and patrilineal communities. Thus, contemporary gender inequalities in education and material wealth may be owing to cultural lag [96,97] rather than to underlying socio-ecological drivers of sex-biases in resource-reproductive success conversion. This has implications for how we design interventions to promote gender equity [98,99]: bio-economic incentives thought to be important in driving initial differences in family structure are likely to be important in equalizing gender-biased investments (e.g. [57]), as are cultural processes associated with ethnic identity [100,101] and acculturation to surrounding norms and opportunity structures. Matrilineal Mosuo women may be exceptionally autonomous, even relative to other matrilineal cultures where power is more clearly held by men; there are





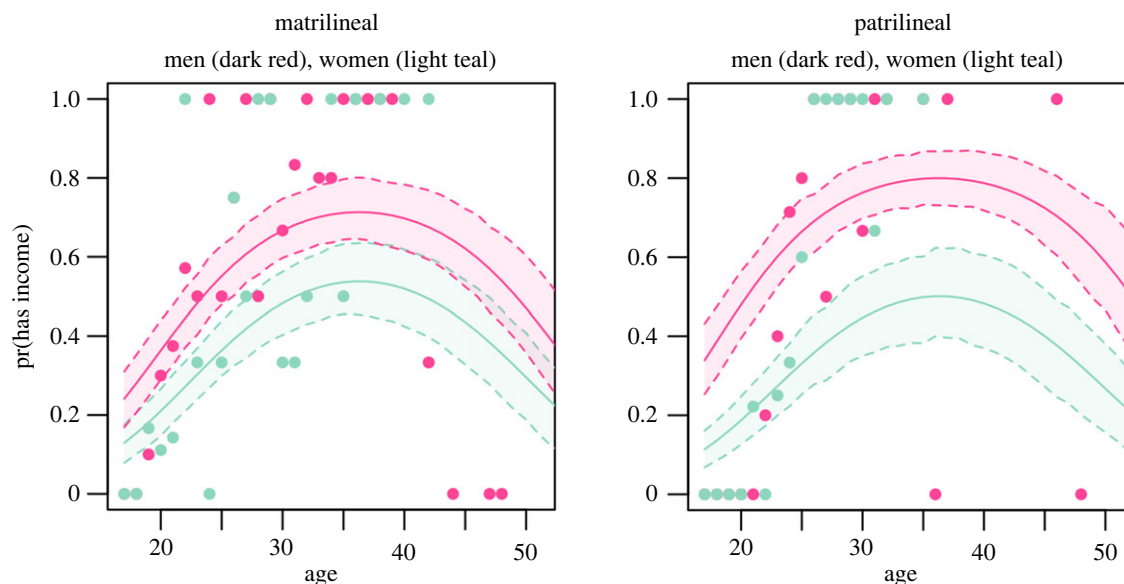
**Figure 3.** Model effects plot for the log odds of reporting an income (a), parameter estimates of income (amount) (b) and the log odds of educational attainment (c). The error bars represent robust 95% confidence intervals (y.o., year old). (Online version in colour.)

important variations in social and normative structures that belie simplistic mapping of ‘kinship systems’ onto differences in gendered behaviour and outcomes [102].

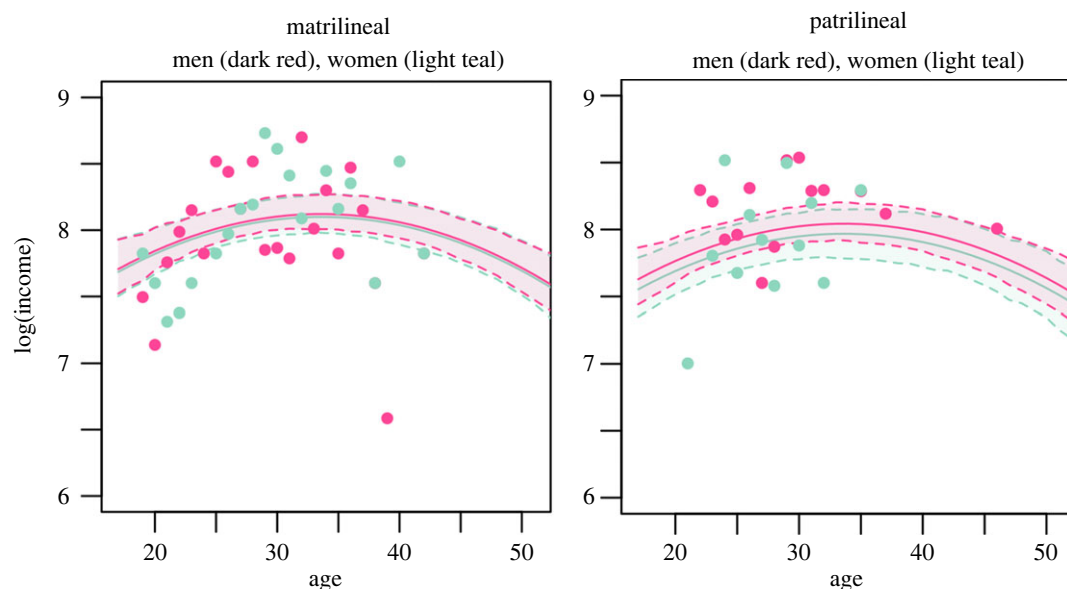
Our analysis reveals additional routes to resource acquisition, some of which appeared to operate differently based on one’s gender. Fluency in Chinese strongly predicted reporting an income, consistent with results described in other mixed economies [8]. As suggested above, fluency in Chinese may provide relatively direct access to material resources for women engaged in local markets, handicraft production, and tourism ventures, whereas education, which is biased towards men more in matriliney than in patriliney, may reflect wider opportunity structures that (as in many parts of the globe) disproportionately favour men.

This reinforces the importance of local contexts in understanding gendered opportunity structures.

Interestingly, one’s parents’ fluency in Chinese predicted one’s educational attainment. This finding echoes others that demonstrate the importance of historical advantage in perpetuating long-run inequality [103–105]. This is especially remarkable in the Chinese context, where the Cultural Revolution and other political activities explicitly attempted to eradicate and even reverse wealth- and education-based differences among households [103]. Indeed, Chinese language fluency is likely to have been achieved among older individuals in this sample via formal, wealth-based education and opportunities that were less readily available to Mosuo than education is in contemporary contexts, as, since 1989,



**Figure 4.** Empirical frequencies of non-zero income for specific ages, stratified by sex and education level with corresponding model predictions of means (lines) and 89% highest posterior density interval (coloured regions) from the hurdle component (i.e. probability of reporting any income) among Mosuo overall. (Online version in colour.)



**Figure 5.** Observed mean log-income for specific ages, stratified by sex and kinship systems with corresponding model predictions of means (lines) and 89% highest posterior density interval (coloured regions) from the log-linear model component among Mosuo overall. Model estimates apply for individuals with high levels of education and fluency in Mandarin. (Online version in colour.)

education has been mandatory for all Chinese citizens. Thus, studies that fail to consider household contexts may miss important contributions to contemporary inequality, including gendered forms that may be more or less likely to be transmitted in the context of Chinese-speaking households. For example, education is generally shown to promote gender equality, but parental Chinese fluency might do the opposite if it acclimatizes individuals to surrounding patriarchal values. The fact that younger cohorts of both men and women in matrilineal and patrilineal areas were more likely to obtain education than their elders may herald future changes in gender equality and social values among Mosuo. These are important questions for future research.

This paper is subject to a number of important limitations. The data are self-reported, which may introduce reporting biases reflective of underlying cultural norms. If, for example,

matrilineal women systematically over-reported their incomes and matrilineal men under-reported theirs for cultural reasons (and this gender-based reporting pattern were reversed under patriliney), it could create the same patterns we observed. If this were the case, the true inequalities could be less in patriliney and more in matriliney than we concluded. Women were frequently respondents in both matrilineal and patrilineal contexts, however, so that seems an unlikely source of systematic bias. The analyses we describe present gender differences in wealth acquisition in patrilineal and matrilineal contexts, rather than describing differences between men and women in the same household. The latter would be an interesting extension of the present research, and might also reveal differences in bargaining power for women and men under different forms of post-marital residence [106]. In the Mosuo case, women often co-reside with their brothers, whose motivations for conflict

and cooperation differ from those between husbands and wives. Finally, it is worth mentioning that men play a variety of roles in Mosuo society [65], such as mothers' brothers, that complicate essentializing women and men into simplistic categories as analysed here. There is also a pressing need to go beyond two-gender models to incorporate broader variation in gender and gendered behaviour in behavioural ecological models [107]. Finally, income is not wealth (it is a flow rather than a stock). The extent to which it is converted to wealth rather than consumed, and the ways in which it is consumed and converted to reproductive success, vary between women and men and across cultures in ways that are not captured here [88]. We did not have access to other asset-based measures of individual wealth in our dataset; income was the best measure we had for material resources.

In conclusion, gender inequality in resources, status and reproduction is ubiquitous, yet varies in degree and kind in different contexts across space and over time. Understanding what produces such variation requires consideration of both cultural norms, as is common in public health, and the underlying ecologies that are associated with and ultimately may help generate such norms. In this paper, we attempted to explain why differences in resources might ultimately be tied to differences in inequality, generally, as well as to divergence between the genders more specifically. We argued that these two dimensions of inequality are intimately intertwined—that where the potential for general inequality is greatest, so, too, is the potential for divergence between genders. Future research, including applied research, would do well to consider the suite of economic, ecological and cultural incentives that shape gendered reproductive agendas [47,96,99,108–110].

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**Data accessibility.** Data files and the R script for this paper can be found at <https://github.com/pmmattison/MosuoGenderInequality2023>.

**Authors' contributions.** S.M.M.: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, supervision, visualization, writing—original draft, writing—review and editing; P.M.M.: data curation, formal analysis, project administration, visualization, writing—original draft, writing—review and editing; B.A.B.: data curation, formal analysis; R.L.: data curation, formal analysis, writing—review and editing; T.B.: funding acquisition, investigation, project administration, supervision, writing—review and editing; C.-Y.S.: data curation, investigation, project administration, writing—review and editing; M.K.S.: funding acquisition, methodology, project administration, supervision, writing—review and editing; E.S.: writing—review and editing; S.A.: writing—review and editing.

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## Endnote

<sup>1</sup>'Wealth' in economics classically refers to assets, stocks, or capital: i.e. reserves of resources. We use 'resources' as a more general term to refer to the goods and services that enable individuals to function and pursue reproductive success, regardless of whether the resources are durable.

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