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Resource Competition and Reproduction in Karo Batak Villages

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Abstract When wealth is heritable, parents may manipulate family size to optimize the trade-off between more relatively poor offspring and fewer relatively rich ones, and channel less care into offspring that compete with siblings. These hypotheses were tested with quantitative ethnographic data collected among the Karo Batak—patrilineal agriculturalists from North Sumatra, Indonesia, among whom land is bequeathed equally to sons. It was predicted that landholding would moderate the relationship between reproductive rate and parental investment on one hand, and the number of same-sex siblings on the other, among boys but not girls. The predicted interaction effect was observed in interbirth intervals and immunizations, but only a trace of the effect was detected in age-five mortality. The study raises questions about the coevolution of human behavior and social structure.

Keywords Interbirth intervals · Patrilineality · Landownership · Inheritance · Child health

The central tenet of human behavioral ecology is that humans have been shaped by natural selection on genetic and cultural variation to behave in ways that maximize inclusive fitness given prevailing ecological conditions (Borgerhoff Mulder 1991; Cronk 1991c; Smith and Winterhalder 1992; Winterhalder and Smith 2000). The framework assumes, among other things, that ignoring the genetic, developmental, and historical constraints on adaptation is valid, and that the behavior of interest has had time to equilibriate to local conditions (Winterhalder and Smith 2000). This perspective has blossomed into a number of productive areas of research, including the analysis of human reproductive and parental strategies (e.g., Borgerhoff Mulder 1992; Mace 2000; Voland 1998), which are the focus of this study. Most behavioral ecology models of these phenomena center on decisions over the allocation of

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resources (e.g., time, energy, and material) to various components of parental and offspring fitness, leaning heavily on the pioneering work of mid to late twentieth-century ecologists and sociobiologists (e.g., Gadgil and Bossert 1970; Pianka and Parker 1975; Smith and Fretwell 1974; Trivers 1972; Williams 1966). The optimal strategy is the one that finds the best trade-off between the fitness costs and benefits given ecological context.

Many of these models can be applied to human reproductive decision-making without modification, even when dealing with unique aspects of the human breeding system. For instance, humans transmit wealth intergenerationally. Theoretical treatments incorporating this have shown that when wealth is heritable, reproductive and parental strategies are a trade-off between more relatively poor ("quantity") and fewer relatively rich ("quality") offspring. Strategies leaning toward quality tend to maximize fitness, as measured by number of grandoffspring (Borgerhoff Mulder 2000; Mace 1998; Rogers 1994). This effect is magnified when offspring require a certain level of wealth to become viable breeders. For example, in their study of historical Germany, Voland and Dunbar (1995) found that, among sons, infant mortality and probability of emigration increased, and probability of marriage decreased, with the number of same-sex sibs among landholding farmers, but not among landless laborers. They interpret these patterns as a consequence of resource competition—emigration and poor marriage prospects owing to a shortage of available breeding spaces, and increased infant mortality owing to parental manipulation of offspring number and, thus, pressure on heritable resources.

Additionally, it might be expected that offspring receive higher levels of investment when they are less likely to compete for mates (Hamilton 1967) or resources (Clark 1978) with their siblings and parents. The latter, referred to as *local resource competition,* was first proposed to explain biased sex ratios in galagos, and it has been used to explain biases in other primates (Silk 1983; Van Schaik and Hrdy 1991). Sieff (1990) suggested that the model might prove a useful alternative to the Trivers-Willard model for explaining biased sex ratios in humans (Trivers and Willard 1973). Cronk (1991a) reviewed a number of cases of sex-biased parental investment in humans, including his own research among the Mukogodo of Kenya, showing that some were better explained by local resource competition, and others by Trivers-Willard or other alternatives. Borgerhoff Mulder (1998) found that the applicability of these models, among the Kipsigis of Kenya, varied by offspring sex, sibship composition, and phase of the lifecourse. Further, she has examined patterns of kin cooperation and conflict given landholdings in the same population with a local resource competition framework (Borgerhoff Mulder 2007).

The Karo Batak, among whom sons inherit equal portions of land from their fathers (Portier and Slaats 1987), pose a problem that might be solved with this theoretical perspective. Surplus sons compete with their brothers for parental land and, thus, it is expected that parents who own land will manipulate their reproductive rates and investment in sons based on the number of sons they already have. This assumes that parental land is the most important resource over which sons compete, and that parental decisions are made in respect to this constraint. Perhaps this downplays the importance of other resources that play an increasingly important role in offspring success in modern Indonesia, such as parental funding for school. Nonethless, it is reasonable that the fate of the family estate should play a crucial role in shaping parental investment decisions in agricultural societies given its importance for offspring marriage and reproductive success (e.g., Hrdy and Judge 1993; Lancaster and Lancaster 1987).

In this paper, bivariate and multivariate analyses with data from two Karo Batak villages were used to test the following hypotheses: (1) the relationship between the number of sons and reproductive rate, on one hand, and the number of sons and parental care, on the other, should be moderated by landholding—in other words, an interaction effect should be observed; (2) there should be no such effect among the sons of landless parents; and (3) there should be no such effect among the daughters of either landholding or landless parents. The interaction framework used here provided a robust set of tools for testing hypotheses about the moderating role of one variable on the relationship between two others (Jaccard and Turrisi 2003), and it has been used to address similar questions in other human behavioral ecology studies (e.g., Borgerhoff Mulder 2007; Quinlan et al. 2003).

Ethnographic Background

The Karo are one of six Batak *suku* (approximately "tribe" or "ethnic group") with traditional homelands in North Sumatra, Indonesia (Kipp 1993; Kushnick 2006; Singarimbun 1975; Steedly 1993). Although many Karo Batak have resettled elsewhere, those in this area live in scattered, ethnically homogeneous villages on or adjacent to the highland plateau. Referred to as Taneh Karo, this area consists of the entire Karo Regency (the administrative unit just north of Lake Toba and west of Medan), but also bordering areas of adjoining regencies, such as Langkat, Dairi, Deli Serdang, Simalungun, and Aceh Tenggara (Fig. 1). A typical Kato Batak village is arranged in a densely populated core, with fields and gardens on the periphery.

The majority of Karo Batak people in this area practice a mix of subsistence and cash-crop agriculture, but some also engage in small-scale entrepreneurialism (e.g., coffee shops, convenience stores, and transportation services), professional work (e.g., nurses, teachers, and civil servants), and wage labor. Many aspects of traditional Karo Batak life have disappeared or changed since first contact with nineteenth-century missionaries (Kipp 1987; Penny and Singarimbun 1967). Most families live in modern-style houses rather than traditional longhouses; they are religiously plural, practicing Christianity, Islam, and animism, rather than solely animism; they have not practiced cannibalism or intervillage warfare for more than 100 years; and their farming practices have shifted from horticulture with possibly usufruct land rights to more-intensive methods and private land tenure. Other aspects of traditional Karo Batak life have remained relatively unchanged. For instance, although schoolchildren learn Bahasa Indonesia, most villagers converse primarily in Bahasa Karo, and their practice of patrilineality, and the social institutions surrounding it, including a stated preference for sons, remains intact.

Arable farmland is a precious commodity owing to Taneh Karo's finite area and increasing population density. Further, because of favorable geography and the introduction of temperate-climate vegetables in the early twentieth century, Karo Batak families today sell crops (to middlemen) for consumption in regional and international markets. This has led to a shift from long-fallow farming to intensive

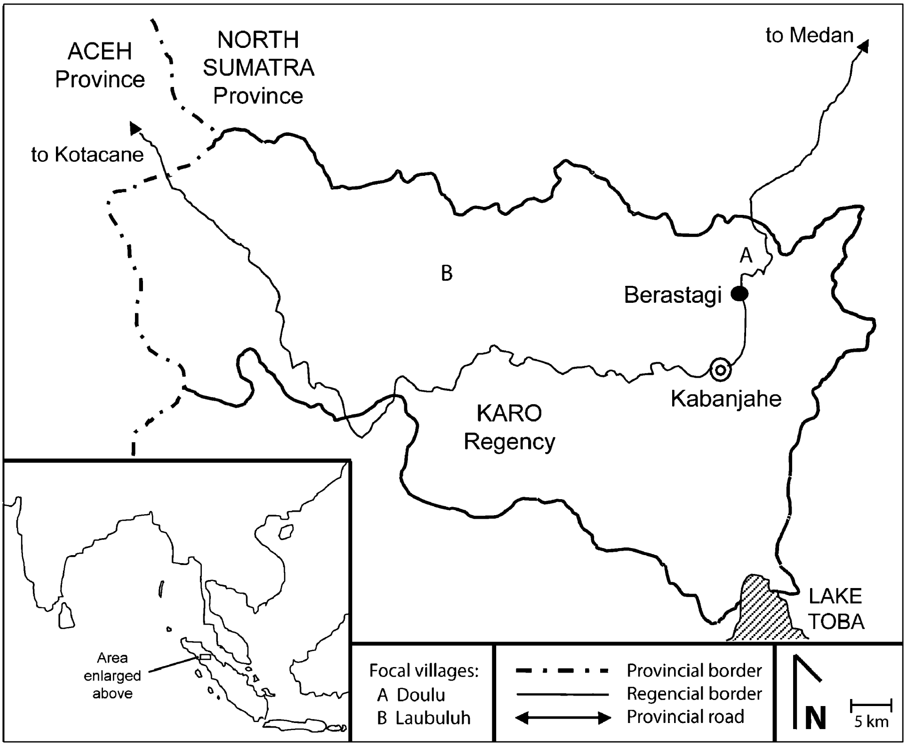


Fig. 1 Map of Taneh Karo, which includes the Karo Regency and surrounding areas

dry-farming methods that require fertilizers and pesticides, and wet-rice farming methods in areas that can accommodate it. Although usufruct rights and ultimogeniture have been reported as past practices (Loeb 1935), today land is divided among sons upon the death of their parents (Portier and Slaats 1987). The Karo Batak refer to this as *pembagin taneh,* or dividing land. Sometimes parents allow their sons to use portions of the land before their death, especially when the parents are too old to use the land themselves. Although daughters are entitled to other property, and are sometimes given permission to use land by their brothers, most parents are hesitant to transfer land rights to a daughter because it then becomes the property of another patrilineage. Portier and Slaats (1987:305) list a handful of phrases in Bahasa Karo that reflect this practice, including *dilaki ngenca berhak* (only sons are entitled) and *diberu la dat kaipa* (daughters receive nothing).

Two Karo Batak villages—Doulu and Laubuluh—were the focus of this study. They provided a fertile testing ground for the ideas presented here because of some key differences that are summarized in Table 1. Doulu is located in a mountainous valley pass (3°13′12″N, 98°32′3″E) approximately 1,200 m (4,000 ft) above sea level. Laubuluh is located in the hilly hinterland that flanks the highland plateau (3°10′50″N, 98°16′12″E) at approximately 1,000 m (3,400 ft) above sea level. Although just about everyone in both villages makes a living by farming, those in Laubuluh are much more likely to own land than those in Doulu. Given this, it is not surprising that people in Doulu are much more likely to rent land than those in

Table 1 Comparisons of Doulu and Laubuluh villages, including demographic parameters, agricultural practices, and sub-regency statistics (Badan Pusat Statistik 1998)

		Doulu	Laubuluh
Demographic			
1. Population		1,003	791
2. Number of households		235	228
3. Total fertility rate		4.38	3.28
4. Age-five mortality rate [a]		37.2	60.4
5. Has ever used contraception		92.1%	53.9%
6. Age of respondent:[b]	Up to 25 y.o.	14	9
	25–30 y.o.	17	23
	31–35 y.o.	19	26
	36–40 y.o.	16	19
	41+ y.o.	20	26
Agricultural			
1. Farming families		91.2%	91.3%
2. Landowning families		54.5%	93.3%
3. Land-renting families		38.0%	7.6%
4. Practices wet-rice farming		55.6%	0.0%
5. Practices dry-rice farming		0.0%	88.3%
6. Practices citrus farming		2.0%	64.2%
Sub-regency[c]			
1. Population density (per km^2)		903	56
2. Area not currently farmed (ha)		0	1,182
3. Sex ratio		102.5	92.7

[a] Per 1,000 at risk

[b] No difference in distribution of respondent ages (χ^2=2.61, p=0.625)

[c] From Bureau of Statistics, Karo Regency (BPS 1998)

Laubuluh. Most folks in Doulu grow wet rice and vegetables; most folks in Laubuluh grow dry rice and mandarin oranges. Geographic constraints may have shaped these differences. Doulu is cut by narrow streams that make wet-rice farming possible and is surrounded by steep, forested mountainsides that effectively limit the amount of arable land in the vicinity. Laubuluh is surrounded by gently rolling hills that are amenable to planting. Further, in Doulu's subregency, no available land remains for establishing new fields; the opposite is found in Laubuluh's subregency. It should be emphasized, however, that despite the availability of unfarmed land, it is not freely available for the taking.

Interestingly, differences in a number of village-level demographic traits support a resource competition interpretation of parental manipulation of reproductive rates and parental investment (Table 1). Despite an overwhelming difference in contraceptive use that would suggest the converse, the total fertility rate of women in Doulu is slightly more than a child higher than that in Laubuluh. This difference in childbearing cannot be explained in terms of a cohort effect either; there is no statistically detectable difference between villages in the age distribution among the women studied. Additionally, the comparisons suggest a difference in the fate of children born alive—age-five mortality in Laubluh is much higher than in Doulu. Finally, the population sex ratio in the sub-regency that contains Doulu is about on par with the rest of the Karo Regency, but the figure for the sub-regency containing Laubuluh is the lowest in the regency—suggesting manipulation of male births, excess male mortality, or a higher male out-migration rate. A stronger conclusion might be drawn about resource competition if similar effects were observed in a comparison of landholders versus landless while controlling for village-level effects.

Methods

Data Collection and Sample

The analyses presented here are based on quantitative ethnographic fieldwork in Doulu and Laubuluh villages from November 2003 to November 2004. Data were collected with a sample of ever-married women between 15 and 65 years old (n=240), yielding information on their children (n=625), among whom the sex ratio was 0.953. Reproductive, marriage, child mortality, and immunization histories were collected retrospectively. Household economic information was collected cross-sectionally—data reflect the situation at the time of study rather than across the family formation period. All interviews were conducted in Bahasa Indonesia or Bahasa Karo with the help of female research assistants.

Separate analyses were done for sons (n=305) and daughters (n=320). Records with missing values for the variables of interest were excluded on an analysis-by-analysis basis. Twins, adopted children, and the children of mothers who have been married more than one time, or once but noncontinuously, were excluded from all analyses. The exlusion based on marriage history was necessary because economic histories were cross-sectional and, thus, it would be impossible to disentangle the complex web of heirships and inheritance expectancies among those children without additional data.

Variables

The dependent variables in this study were measures of reproductive rate and parental investment. Reproductive rate was measured as the interbirth interval (IBI)—the temporal span in months between consecutive births, or between the most recent birth and the date of study for right-censored observations. The closing dates for IBIs in women older than 45 years old at the time of study were truncated to the date of their forty-fifth birthday based on the assumption that this is the end of their reproductive span. The child of interest in these analyses was the one whose birth opened the interval. Two measures of parental care were used. First, age-five mortality (M_5) was defined as death within the first 60 months of life and was measured as a continuous variable (i.e., age in months at death). Age was truncated to 60 months in older children. Second, number of immunizations, was treated as a count with values from 0 to 9.

There were three predictors of interest in this study—two measured variables and their interaction term. First, the number of sons or daughters already in the sibship on the date of birth of the focal child (aka "same-sex siblings" or SSS) was treated as a dummy variable (0=no SSS, 1=at least 1 SSS). Second, parental landholding (aka "land") was treated as two dummy variables (0=landless, 1= landholder; or 0=0 to 2.49 ha, 1=at least 2.5 ha). The interaction terms were the product of the values for SSS and land variables. Thus, when the landholding variable and SSS variable equaled 1, the interaction term was also 1; all other values of landholding and SSS led to an interaction term value of zero. This allowed for testing the hypothesis that landholding played a moderating role between SSS and the dependent variables among sons but not daughters—that there is something different in the relationship between number of brothers and the dependent variable of interest among landholders but not the landless (Jaccard and Turrisi 2003).

A number of control variables were also included in the analyses: birth order, village, mother's education and age, child's age, and age-one mortality (Table 2). Birth order was treated as a continuous covariate. When the focal child had older siblings that were twins, they were counted as a single birth for the calculation of birth order. So, for example, if a mother's first pregnancy resulted in twins and her second in a singleton birth, the child from the second pregnancy was coded as birth

Table 2 Descriptive statistics for independent variables

Variable		*n*	Mean	SE
1. Birth order[a]		495	2.26	0.06
2. Mother's age (yrs.)[a]		495	26.60	0.24
3. Village	1=Laubuluh	254	–	–
	0=Doulu[b]	241	–	–
4. Age-one mortality	1=Died	17	–	–
	0=Survived[b]	478	–	–
5. Child's age (yrs)	<1[c]	34	–	–
	1–6[d]	160	–	–
	7–26[e]	282	–	–
	26+ [b,f]	19	–	–
6. Mother's education	1=At least some Sr. High School	225	–	–
	0=No Sr. High School[b]	261	–	–

[a] Continuous variable

[b] Reference category

[c] Immunizations likely to be incomplete

[d] Born after addition of Hepatitis B vaccine (3 doses) in 1997

[e] Born after initiation of vaccination program in 1977

[f] Born before initiation of vaccination program in 1977

order 2. Village was treated as a dummy variable. This is a particularly important control variable because, without it, any effect of landholding (including the interaction effect) could be a spurious relationship caused by most observations of landlessness occurring in Doulu. Mother's education was treated as a dummy variable. Mother's age was her age in years at the birth of the focal child and was only included in the IBI analyses. Child's age was only included in the immunization analyses. It was treated as three dummy variables corresponding to completing the first year of life (because there is little expectation of additional immunizations beyond that age) and a series of landmark years for Indonesia's immunization program (Badan Pusat Statistik and ORC Macro 2003). Age-one mortality—death within the first 12 months of life—was treated as a dummy variable and included only in immunization analyses.

Statistical Analyses

Both bivariate and multivariate statistical analyses were used to address whether landholding moderates the relationship between the number of brothers, on one hand, and reproductive rate (IBIs) and parental care (M_5 and immunizations), on the other. All of the analyses were done using Stata 10. Statistical significance was set at $\alpha=0.5$, but marginally significant effects (i.e., $p<0.10$) are flagged and discussed where relevant.

IBIs and M_5 were analyzed using Kaplan-Meier (K-M) estimates and Cox proportional hazards regression (Box-Steffensmeier and Jones 2004; Cleves et al. 2008). These methods are standard for handling duration data with right-censoring. Survivorship functions, estimated with K-M estimates of the hazard of failure, were compared with Breslow χ^2 tests. Cox regression was used to model the effects of covariates on the survivorship functions, and Wald χ^2 tests were used to test whether the effects were statistically significant. Shorter IBIs and more severe M_5 occurred when the hazard of experiencing the event is greater. Visually, these effects are represented by steeper survivorship curves. Hazard ratios (HRs) were also used to measure effects of covariates in the regression models, and they were calculated by simply exponentiating the estimated coefficient. The HR measures the change in the hazard for a one-unit increase in the covariate. Bivariate analyses of immunizations were conducted using Mann-Whitney U-tests. Poisson regression, the preferred modeling technique for count data, was used to model the effect of covariates on the predicted number of immunizations (Gelman and Hill 2007; Rabe-Hesketh and Skrondal 2008). Wald χ^2 tests were used to test whether the effects were statistically significant.

All of the regression models included the predictors of interest—same-sex siblings, land, and their interaction term—as well as a number of covariates chosen for theoretical reasons (see above). Because the sample included multiple children from the same sibship, observations were not assumed to be independent. For this reason, each regression model also included adjustments for repeated measures with shared frailty models in Cox regression (Box-Steffensmeier and Jones 2004) and Gaussian random-intercept models with poisson regression (Gelman and Hill 2007). Clusters were defined by the focal mother's unique identifier. Following Gelman and Hill (2007), these adjustments were included in the models even when the hypothesis that the variance parameter for the frailty and random-effects submodel equaled 0 could not be rejected.

Results

Interbirth Intervals

Bivariate Bivariate analyses of IBIs are summarized in Table 3. As predicted, landholding appears to have played a moderating role on the relationship between number of same-sex siblings and IBIs in sons, but not daughters. (A) Sons: The median IBI following the birth of a son with at least one brother at the time of birth was significantly longer than those following sons with no brothers; the median IBI following the birth of a son among landowners was longer than among the landless, but the difference was not statistically significant. When the comparison was stratified by landholding, the interaction effect was clear (Fig. 2). Among landowners, median IBI following the birth of a son with at least one brother was 33 months longer than median IBI following the birth of a son with no brothers, and

Table 3 Bivariate analyses of IBI, M_5, and immunizations

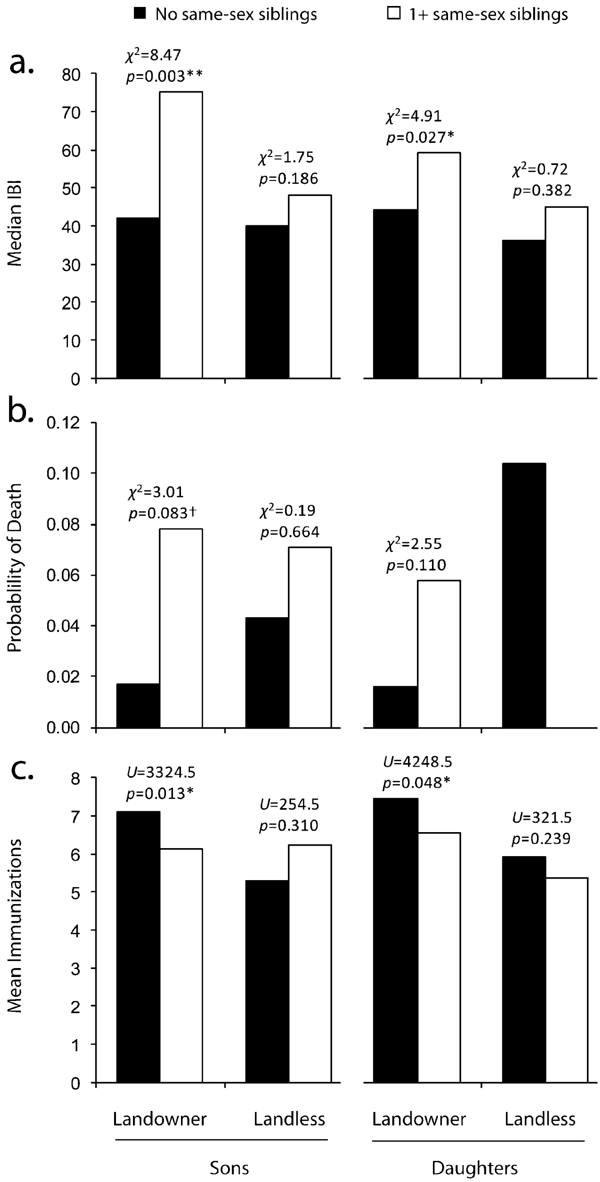
		Sons			Daughters		
IBI (in months)[a]		*n*	Median	SE[c]	*n*	Median	SE[c]
Overall		239	46	1.659	256	46	1.647
Same-sex siblings	0 SSS	139	42	3.988**	141	43	1.766*
	1+ SSS	100	65	0.792	113	54	2.881
Landholding	Landowners	186	50	1.652	199	48	1.760
	Landless	53	41	1.255	57	43	1.364
Age-Five Mortality[a]		*n*	Prop.	SE[c]	*n*	Prop.	SE[c]
Overall		254	0.043	0.013	304	0.039	0.012
Same-sex siblings	0 SSS	168	0.024	0.012	168	0.033	0.015
	1+ SSS	83	0.067	0.030	129	0.040	0.018
Landholding	Landowners	189	0.040	0.015	226	0.038	0.013
	Landless	64	0.048	0.027	75	0.047	0.027
Immunizations[b]		*n*	Mean	SE[c]	*n*	Mean	SE[c]
Overall		237	6.44	0.179	260	6.77	0.158
	0 SSS	138	6.70	0.236†	145	7.12	0.190*
Same-sex siblings	1+ SSS	98	6.14	0.269	113	6.27	0.262
Landholding	Landowners	185	6.69	0.205**	204	7.07	0.173***
	Landless	51	5.67	0.335	56	5.66	0.341

[a] Comparison of survivorship functions (Kaplan-Meier estimates) using Breslow χ^2 tests

[b] Comparison of mean using Mann-Whitney U-tests with no equal-variance assumption

[c] Significance: † $p<0.10$, *$p<0.05$, **$p<0.01$, ***$p<0.001$

Fig. 2 Stratified bivariate analyses of **a** IBIs, **b** M_5, and **c** immunizations. Comparisons of Kaplan-Meier survivorship functions use Breslow χ^2 tests. Comparisons of mean immunizations use Mann-Whitney U-tests



the difference was statistically significant. Among the landless, the difference was only 8 months and was not statistically significant. (B) Daughters: The median IBI following the birth of a daughter with at least one sister at the time of birth was significantly longer than those following daughters with no sisters; the median IBI following the birth of a daughter among landowners was longer than among the landless, but the difference was not statistically significant. When the comparison was stratified by landholding, the lack of an interaction effect was clear (Fig. 2). The difference between median IBIs following the birth of a daughter with at least one sister and median IBIs following the birth of a daughter with no sisters was similar for both landowners (15 months) and the landless (9 months), and neither difference was statistically significant.

Multivariate Multivariate analyses of IBIs are summarized in Table 4. Each analysis was a Cox regression model with shared frailty (to adjust for the nonindependence of observations) and covariates for the predictors of interest (same-sex siblings, land, and the interaction of the two) and control variables (birth order, village, and mother's age at time of birth). As predicted, there is strong evidence of an interaction effect in sons, but not daughters. (A) Sons: An interaction effect among sons emerged when land was coded as a dummy variable for "owns at least 2.5 ha" but not in the model that coded land as a dummy variable for "landowner." The covariates for birth order, village, mother's age, land, and the interaction term were statistically significant. The covariate for same-sex siblings was only marginally

Table 4 Multivariate analysis of IBIs: Cox regression models with shared frailty to adjust for multiple observations from the same sibship

Model Parameters		Sons[a]			Daughters[b]		
		HR	SE	p[c]	HR	SE	p[c]
1. Birth order		0.553	0.078	0.000***	0.611	0.072	0.000***
2. Village	Laubuluh	0.568	0.104	0.002**	0.560	0.092	0.000***
	Doulu[d]	–	–	–	–	–	–
3. Mother's age (yrs.)		0.941	0.021	0.007**	0.932	0.021	0.002**
4. Mother's education	At least some Sr. High School	1.015	0.187	0.934	1.030	0.179	0.866
	No Sr. High School[d]	–	–	–	–	–	–
5. Same-sex siblings	1+ SSS	1.549	0.388	0.081†	1.916	0.443	0.005**
	No SSS[d]	–	–	–	–	–	–
6. Land	0–2.49 ha.	1.699	0.429	0.036*	0.980	0.241	0.934
	2.5+ ha.[d]	–	–	–	–	–	–
7. Interaction		0.385	0.153	0.016*	0.926	0.338	0.834
(SSS × Land)							
Shared Frailty		Variance	SE	p[c]	Variance	SE	p[c]
Theta		0.017	0.129	0.448	<0.000	<0.000	0.499

[a] Model: n=233, log likelihood=−628.3, likelihood ratio test χ^2 =79.7, df=6, p<0.001

[b] Model: n=249, log likelihood=−737.4, likelihood ratio test χ^2 =67.8, df=6, p<0.001

[c] Significance: † p<0.10, *p<0.05, **p<0.01, ***p<0.001

[d] Reference category

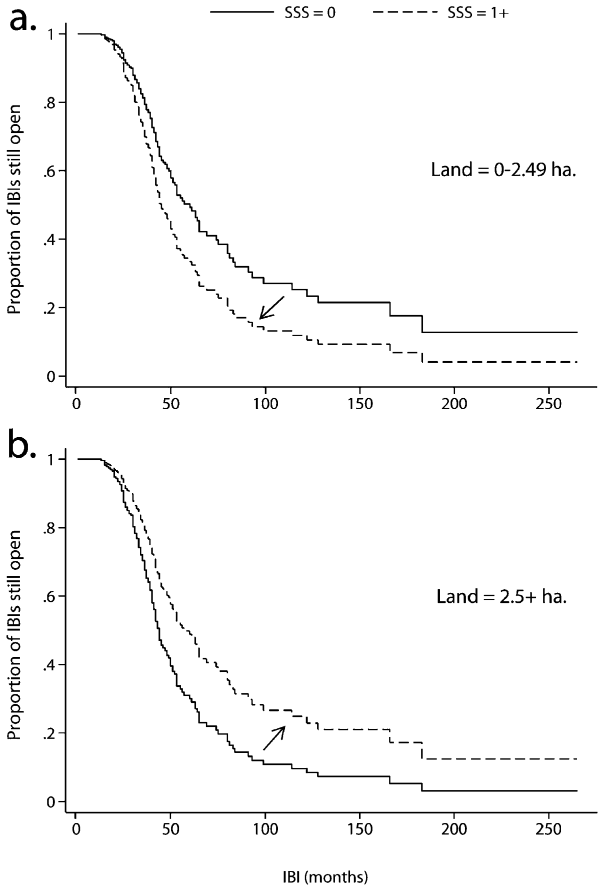


Fig. 3 Model estimates of the proportion of IBIs still open by month in boys, illustrating the moderating effect of landholding on the relationship between number of same-sex siblings and reproductive rate (*arrows* show direction of increasing number of same-sex siblings). The panels illustrate landholdings **a** 0 to 2.49 ha and **b** 2.5 ha and greater

significant. This cluster of effects is illustrated in Fig. 3 and described as follows: Among the landless and those with small landholdings, IBIs following the birth of a son with at least one brother were shorter than those following the birth of a son with no brothers. Among those with larger landholdings, the opposite was seen—IBIs following the birth of a son with at least one brother were longer than those following the birth of a son with no brothers. (B) Daughters: Although the model of IBIs following the birth of a daughter was a good fit for the data, there was no detectable interaction effect. This was the case in models with land coded as "owns at least 2.5 ha" (Table 4) and "landowner" (not included in table).

Age-Five Mortality

Bivariate Bivariate analyes of M_5 are summarized in Table 3. As predicted, landholding appears to have played a moderating role on the relationship between the probability of death and number of same-sex siblings in sons, but not daughters. (A) Sons: Sons with at least one brother at birth had an almost three times higher probability of dying in the first five years than did those with no brothers. Sons of the landless had a slightly higher probability of dying than sons of landholders. Neither difference was statistically significant. When stratified by landholding (Fig. 2), sons of landowners with at least one brother had an almost five times higher probability of dying than those with brothers, and the difference was marginally significant. The same pattern was observed among the landless, but the difference was much more modest and was not statistically significant. (B) Daughters: Daughters with at least one sister at birth had a slightly higher probability of dying than those with no sisters, as did daughters of the landless compared with those of landowners. Neither difference was statistically significant. When stratified by landholding (Fig. 2), daughters of landholders showed a pattern similar to that seen among boys, but the difference was not statistically significant. Among the landless, mortality among daughters with no sisters at birth was extremely high, but not among those with at least one sister.

Multivariate Multivariate analyses of M_5 proved challenging. Each analysis was a Cox regression model of time to death with shared frailty to control for the nonindependence of observations. There were no significant interaction effects in either of the models. In fact, none of the models—even those with minimal covariates—was a good fit to the data.

Immunizations

Bivariate Bivariate analyes of immunizations in children at least 12 months old are summarized in Table 3. As predicted, landholding appears to have played a moderating role on the relationship between mean immunizations and number of same-sex siblings in sons, but not daughters. (A) Sons: Sons with at least one brother at birth received fewer immunizations than those with no brothers, but the difference was only marginally significant; sons of landowners received significantly more immunizations than the sons of landless parents. When the comparison of mean immunizations by number of brothers was stratified by landholding, the predicted interaction effect was clear (Fig. 2). Among landowners, sons with at least one brother at birth received fewer immunizations than those with no brothers, and the difference was statistically significant. Among the landless, the opposite was observed—sons with at least one brother at birth received more immunizations than those with no brothers, but the difference was not statistically significant. (B) Daughters: The bivariate data from daughters were similar to the bivariate data from sons. Daughters with at least one sister at birth received fewer immunizations than those with no sisters, and the difference was statistically significant; daughters of landowners received significantly more immunizations than the daughters of landless parents. When the comparison of mean immunizations by number of sisters was stratified by landholding, as predicted, there was no interaction effect. In both landholding categories, daughters with at least one sister at birth received less immunizations than those with no sisters. Although, the difference in mean immunizations among landowners (0.88) was statistically significant, and the difference among the landless (0.58) was not, the relationships are not substantively different (i.e., there is no interaction effect).

Table 5 Multivariate analysis of immunizations: Poisson regression models with random effects to adjust for multiple observations from the same sibship

Model Parameters		Sons[a] β	SE	p[c]	Daughters[b] β	SE	p[c]
1. Constant		1.541	0.151	–	1.095	0.207	–
2. Birth order		−0.055	−0.028	0.049*	−0.015	0.027	0.584
3. Village	Laubuluh	0.344	0.060	0.000***	0.317	0.055	0.000***
	Doulu[d]	–	–	–	–	–	–
4. Child's age (yrs)	0–1	−0.647	0.297	0.029*	0.316	0.231	0.172
	1–6	0.116	0.131	0.378	0.619	0.199	0.002**
	6–26	0.080	0.127	0.527	0.622	0.193	0.001**
	26+ [d]	–	–	–	–	–	–
5. Age-one mortality	Died	−2.021	0.449	0.000***	−30.980	>1000	1.000
	Survived [d]	–	–	–	–	–	–
6. Mother's education	At least some Sr. High School	0.094	0.054	0.083†	0.113	0.513	0.028*
	No Sr. high school[c]	–	–	–	–	–	–
7. Same-sex siblings (SSS)	1+ SSS	0.282	0.123	0.022*	−0.072	0.118	0.542
	No SSS[d]	–	–	–	–	–	–
8. Land	Landowner (1+ ha.)	0.163	0.094	0.081†	0.074	0.086	0.392
	Landless (0 ha.)[d]	–	–	–	–	–	–
9. Interaction		−0.306	0.133	0.022*	0.026	0.124	0.834
(SSS × Land)							
Random Effects		Variance	SE	p[c]	Variance	SE	p[c]
Sigma		0.000	0.046	1.000	0.000	0.003	1.000

[a] Model: n=236, log likelihood=−540.5, likelihood ratio test χ^2 =97.59, df=8, p<0.001

[b] Model: n=260, log likelihood=−560.1, likelihood ratio test χ^2 =88.40, df=8, p<0.001

[c] Significance: † p<0.10, *p<0.05, **p<0.01, ***p<0.001

[d] Reference category

Multivariate Multivariate analyses of immunizations are summarized in Table 5. Each analysis was a Poisson regression with random effects (to adjust for the nonindependence of observations) and covariates for the predictors of interest (same-sex siblings, land, and the interaction of the two) and control variables (birth order, village, child's age, survival to 1 year of age, and mother's education). As predicted,

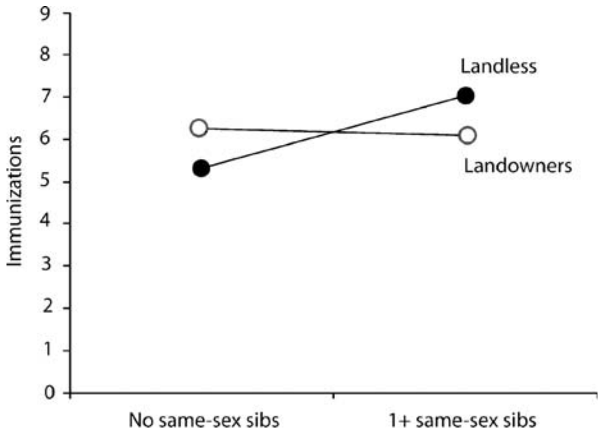


Fig. 4 Model estimates of mean immunizations in boys, illustrating the moderating effect of landholding on the relationship between number of same-sex siblings and parental care

there was strong evidence of an interaction effect in sons, but not daughters. (A) Sons: A statistically significant interaction effect emerged in the model. In addition, the estimates for birth order, village, child's age, survival to 12 months of age, and same-sex siblings were statistically significant. The estimate for landownership was marginally significant. This cluster of effects is illustrated in Fig. 4 and described as follows: Among landowners, the mean number of immunizations is lower for sons with at least one brother at birth relative to those with no brothers. The opposite relationship is observed among the landless. (B) Daughters: Although the model of IBIs following the birth of a daughter was a good fit for the data, there was no detectable interaction effect.

Discussion

The analyses presented here support a resource competition interpretation of reproductive and parental strategies in Doulu and Laubuluh villages. First, landholding moderated the relationship between number of brothers and reproductive rate. In the bivariate analyses, as predicted, the difference between median IBIs following sons with no brothers and those following sons with at least one brother was much greater among landholders than among the landless. Also, as predicted, the differences were approximately the same among daughters. In the multivariate analyses, as predicted, a significant interaction effect was detected for sons, but not daughters. The relationship between number of brothers and reproductive rate changed direction at 2.5 ha of land (as illustrated in Fig. 3). In other words, in landless families and those with small landholdings, IBIs were shorter after the birth of a son with at least one brother relative to those with no brothers. In families with landholdings of 2.5 ha or greater, IBIs following the birth of a son with at least one brother were longer than those with no brothers. Second, a trace of the predicted interaction effect was found in the bivariate analyes of M_5 in sons. Among landholders, firstborn sons experienced dramatically lower mortality than later-born sons. The difference in mortality among the landless was much more modest. Unexpectedly, the highest mortality was experienced by first-born daughters in landless families. The multivariate analyses of M_5 were inconclusive. Third, the predicted interaction effect was observed in both bivariate and multivariate analyses of immunizations. Among landowners, sons with at least one brother at birth received significantly fewer immunizations than those with no brothers. Among the landless, the opposite relationship was observed. No interaction effect was detected among daughters.

These observations mesh well with the idea that parents might manipulate family size in relation to agricultural holdings (Voland and Dunbar 1995), and that "surplus" sons in families with patrilineal land transmission will receive lower levels of parental investment because they compete with their brothers for parental resources, a form of local resource competition (Clark 1978). The multivariate analyses allowed for the rejection of some competing hypotheses. For instance, since most of the landless families came from Doulu, the observed effects of landholding might be a spurious effect of intervillage differences. Because the landholding effects stood after controlling for village, this seems unlikely. Some questions, however, remain unanswered. For instance, since plenty of unfarmed land exists in Laubuluh's vicinity, one must wonder why they would limit the number of sons. Historical demographic studies indicate that single-son preferences coevolve with land availability (Hrdy and Judge 1993). Since land is not a free good, it is assumed that Karo Batak do not incorporate this unfarmed land into their holdings because they cannot afford to.

The predicted interaction between reproductive rate (measured as IBIs) and heritable wealth in land was evident. Interbirth intervals following the birth of a son shortened as a function of number of brothers in families owning at least 2.5 hectares of land. This raises at least one interesting question about the inclusive-fitness-enhancing parcel size for a bequest of land: Although we might expect landholders to favor slowed reproductive rates compared with the landless in this context, why do we not see increased reproductive rates with larger landholdings? After all, the larger the landholding, the more sons that can be provisioned with a viable bequest of land. In this dataset, however, no such pattern was detected. One possible explanation is that relatively richer parents (in this case, those with larger landholdings) are more likely to lean toward the "quality" strategy of fewer but relatively rich offspring, and the relatively poorer parents (in this case, the landless and those with smaller landholdings) toward the "quantity" strategy of more but relatively poor offspring (sensu Rogers 1994). In other words, some landowners might be qualitatively more like the landless because they are relatively poor than they are like other landowners. Another possibility is that the reproductive strategy observed among those with large landholdings is adaptive vis-à-vis lineage survival (sensu Boone and Kessler 1999) rather than an adaptation for maximizing short-run fitness.

Are IBIs a good measure of investment in reproductive effort? In one sense they are. Given a finite reproductive span, an individual's reproductive output is inversely related to the average IBI (Smith and Fretwell 1974). In another sense, however, they are an imperfect and misleading measure because a longer IBI can indicate either a slowdown of reproductive rate or an increase in parental effort (a subset of reproductive effort). This is relevant for the analyses presented here because it was assumed that the slowdown of reproductive rate was a manipulation of family size (Voland and Dunbar 1995). It could also be the case, however, that the slowdown marked an increase in parental care allocated to the current offspring. It depends on how the time during that interval is used. If this were the case, the opposite interpretation might apply—that parents are favoring later-born sons. It seems reasonable, however, that the longer IBIs observed among landholders indicate a divestment in reproductive effort for two reasons. First, the concomitant decrease in two measures of parental investment among later-born sons makes it unlikely they are being favored. Second, although increased mortality in "surplus" sons may be a spur to increased parental investment, the median IBIs observed for the groups being compared here far exceed the level at which this would be relevant. For instance, Palloni and Tienda (1986) have shown that the risk of offspring death decreases with length of the IBI up to 24 months. Increasing the IBI from 42 to 75 months (as illustrated in Fig. 2) would presumptively have a negligible effect on offspring mortality.

The contrast between immunizations in landowners and the landless is striking. The decrease in immunizations with an increase in brothers among sons of landowners conforms to the predictions of local resource competition, as does the absence of this pattern among the landless. The dramatic increase in immunizations with increasing brothers among the landless, however, is more challenging to explain. One possibility is that later-born sons are born to mothers with more knowledge of practices, such as immunization, that decrease offspring morbidity and mortality. Another possibility is that immunizations are an inadequate proxy for parental investment. This would be the case, for instance, if their fitness cost to the parent was negligible (Clutton Brock 1991; Trivers 1972). This seems to be an unlikely explanation for two reasons. One, there are costs, though primarily in the form of opportunity costs. In my observation, infant immunizations are a time-consuming affair even when they are administered in the village. Second, if the costs are neglible, they are more so for relatively resource-rich landowners (who conform to prediction) than the relatively resource-poor landless (who seem more difficult to explain). It is also possible that the relative distance of the two villages from urban centers has caused a spurious association between landholding and immunizations. Although plausible, the multivariate analyses provide little support for this explanation; the relationships hold even when controlling for village.

An untested assumption of this study is that the adjustment of reproductive and parental strategies observed here indeed leads to an increase in the inclusive fitness of those parents. Only time can tell. Unlike the historical demographic studies that have explored similar phenomena (e.g., Low 1990, 1991; Low and Clarke 1991; Voland 1995; Voland and Dunbar 1995), this study lacks the time depth and, thus, the multigenerational data to test this assumption. The following additional data will be useful to test this and other important corollary hypotheses: (1) whether the number of surviving grandchildren is indeed greater in families that adjusted their reproductive and parental strategies in the presumptively adaptive way, or if the trade-off logic of life history evolution is more appropriate only for the poorest subsample of those studied (e.g., as found by Lycett et al. 2000); (2) whether the yearly marriage probability for sons varies in a similar manner; (3) whether surplus sons, upon maturity, are more likely to emigrate, seeking oppoturnity elsewhere; and (4) whether the size of sons' actual inheritance is equitable, or instead biased toward early-born sons.

The Karo Batak people studied here adjusted their reproductive and parental strategies based on fitness-shaping aspects of their environment given the constraints of the culturally prescribed system of equal inheritance of land to sons. The inheritance system itself may be a parental strategy that is adapted to local environment (Hrdy and Judge 1993), as could the patrilineal social structure that underlies the system (Collier 1975). This poses a significant challenge to the behavioral ecology approach. At what point do human cultural institutions switch from being ecological features to be navigated by inclusive-fitness-maximizing actors to malleable features of the adaptive system themselves that are adjusted in fitness-enhancing ways? Individual adjustments, also referred to as phenotypic adaptations, work on a much faster time scale and are thus less resistant to change than institutional-level adjustments, or cultural adaptations (Smith 2000). Among the Batak peoples of North Sumatra, for instance, the practice of male-biased inheritance persists even in the face of national-level legislation for gender equality (Ihromi 1994).

This study also provides additional support for Cronk's (1991b, 1999, 2007) finding that what parents say they should do and what they actually do diverge—a mismatch between ideal and real behavior. Among the Mukogodo of Kenya, for example, parents have a stated preference for boys, perhaps because of their affinities with Masai culture, but their actual behavior shows a bias toward girls. In Karo Batak society as a whole, there is a strongly stated preference for boys, but among landholding families later-born sons are appear to be treated as surplus. Although a preference for boys may indeed be present, it is not a generalized preference, as only certain sons benefit.

In conclusion, the idea that parents will adjust their reproductive strategies in ways that maximize inclusive fitness was supported with data from two Karo Batak villages. When wealth is heritable, parents might manipulate their reproductive rates to produce a small number of relatively well endowed offspring, and invest more in offspring that compete less with their siblings. The Karo Batak are patrilineal agriculturalists who bequeath land equally to their sons. In Doulu and Laubuluh villages, the variation in parental landholding enabled testing of the following hypothesis and its corollaries: The relationship between reproductive rates and parental investment, on one hand, and number of brothers, on the other, should be moderated by landowning status. The predicted interaction effect was found in analyses of IBIs and one measure of parental investment—immunizations. A trace of the predicted interaction effect was detected in analyses of age-five mortality.

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