Resource Competition and Reproduction in Karo Batak Villages

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ABSTRACT

Behavioral ecology theory predicts that when wealth is heritable, parents may (a) manipulate family size to optimize the tradeoff between more relatively poor offspring and fewer relatively rich ones, and (b) channel less care into offspring that compete more with their siblings for resources. These hypotheses were tested with 305 Karo Batak boys. The Karo Batak are agriculturalists from North Sumatra, Indonesia, among whom land is bequeathed equally to sons. As predicted, the relationships between reproductive rate and parental investment on one hand, and number of sons on the other, was mediated by landholding. Reproductive rates slowed with increasing sons among families with above-average landholdings, but not among the landless and those with small landholdings. Age-five mortality increased with the number of sons more steeply among landowners than among the landless. Finally, immunizations decreased with the number of sons among landowners, but increased among the landless.

INTRODUCTION

Over the past two decades, an increasing number of scholars have shown that evolutionary theory can inform demographic research (e.g., Turke 1989; Clarke & Low 2001; Kaplan & Lancaster 2003). The central tenet of one such perspective, called 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 1991; Smith and Winterhalder 1992; 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 fitness-enhancing resources (e.g., time, energy, and material) to alternative ends, 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 tradeoff between the fitness costs and benefits given ecological context.

For some problems, these generalized models are insufficient without modification to adequately account for unique aspects of the human breeding system. For instance, humans accumulate wealth and bequeath it to offspring. Theoretical treatments incorporating this have shown that when wealth is heritable, reproductive and parental strategies are a tradeoff between more relatively poor ("quantity") and less relatively rich ("quality") offspring. Strategies leaning toward quality tend to maximize fitness, as measured by number of grandoffspring (Mace 1998; Rogers 1994). This effect is magnified when offspring require a threshold 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 due to a shortage of available breeding spaces, and increased infant mortality due 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 has proven useful for explaining biases in other primates (Silk 1980; Van Schaik and Hrdy 1991). Sieff (1990) suggested that the model might prove a useful alternative to the Trivers-Willard (1973) model for explaining biased sex ratios in humans. Cronk (1991) reviewed a number of cases of sex-biased parental investment in humans, including his own research among the Mukogodo, showing that some were better explained by local resource competition, and others by Trivers-Willard or other alternatives. Borgerhoff Mulder (2007) examined patterns of kin cooperation and conflict given landholdings among the Kipsigis of Kenya with a local resource competition framework.

The Karo Batak, among whom sons inherit equal portions of land from their fathers, pose a problem of 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 their investment in sons based on the number of sons they already have. In this paper, the following hypotheses are tested: (1) among landholding families, reproductive rates should slow as the number of sons increases; (2) sons born into sibships already containing sons should receive lower levels of parental investment from their landholding parents than sons born into sonless sibships; and, (3) neither of these relationships should be found in landless families. Thus, an interaction effect is predicted—i.e., that the relationship between number of sons and reproductive rates on one hand, and number of sons and parental investment on the other, should be mediated by landownership. Both Quinlan et al. (2003) and Borgerhoff Mulder (2007) have used an interaction framework to study similar questions.

ETHNOGRAPHIC BACKGROUND

The Karo are 1 of 6 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 (see 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 19th-Century missionaries (Kipp 1987; Penny and Singarimbun 1967). For instance, 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 and inter-village warfare for over 100 years; and, their farming practices have shifted from horticulture with usufruct

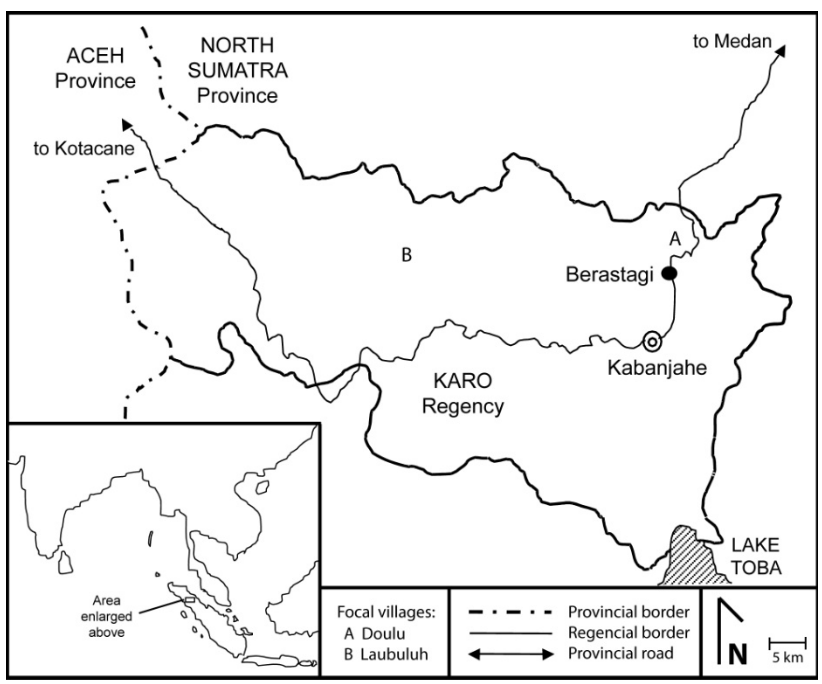

Figure 1. Map of Karo Regency.

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 due to *Taneh Karo*'s finite area and increasing population density. Further, due to favorable geography and the introduction of temperate-climate vegetables in the early 20th 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 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 up amongst 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 their 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'N x 98°32'E) approximately 1,200m (4,000 ft) above sea level. Laubuluh is located in the hilly hinterland that flanks the highland plateau (3°11'N x 98°16'E) at approximately 1,000m (3,400 ft) above sea level. Although more than 90% of the households in these villages make a living by farming, those in Laubuluh are more likely to own land (93.3%) than those in Doulu (54.5%). Given this, it is not surprising that the people living in Doulu are more likely to rent land (38.0%) than those in Laubuluh (7.6%). Most folks in Doulu grow wet rice and vegetables; most folks in Laubuluh grow dry rice and mangarin oranges. Geographic constraints may have shaped these differences (see Fig. 2). Doulu is cut by narrow streams that make wet-rice farming possible, and is surrounded by steep, forested mountain-sides 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 the sub-regency that contains Doulu, there is no remaining unfarmed land that is not allocated for some other use, but in the sub-regency that contains Laubuluh, there remains 1,182 ha.

Interestingly, a number of demographic differences support a resource competition interpretation. Despite an overwhelming difference in contraceptive use that would suggest the converse, the people of Laubuluh show more reproductive constraint (TFR=3.28) than the people of Doulu (TFR=4.38). Additionally, the comparisons suggest a difference in the fate of children born alive—age-five mortality in Laubluh (60.4 in 1,000) is much higher than in Doulu (37.2 in 1,000). Finally, the population sex ratio in the sub-

Table 1. Comparisons of Doulu and Laubuluh villages.

	Doulu	Laubuluh
1. Demography:		
Population	1,003	791
Number of households	235	228
Total fertility rate	4.38	3.28
Age-five mortality rate [a]	37.2	60.4
Has ever used contraception	92.1%	53.9%
2. Agriculture:		
Farming families	91.2%	91.3%
Landowning families	54.5%	93.3%
Land-renting families	38.0%	7.6%
Practices wet-rice farming	55.6%	0.0%
Practices dry-rice farming	0.0%	88.3%
Practices citrus farming	2.0%	64.2%
3. Sub-regency: [b]		
Population density (per km^2)	903	56 [c]
Area not currently farmed (ha.)	0	1,182
Sex ratio	102.5	92.7 [c]
Malaria cases [d]	0.5	90.5
Diarrhea cases [d]	163.0	741.0

[a] Per 1,000 at risk.
[b] From Bureau of Statistics, Karo Regency (BPSKK 1998).
[c] Lowest of the 13 subregencies in the Karo Regency.
[d] Per 10,000 at risk.

regency that contains Doulu (1.027) is about on par with the rest of the Karo Regency, but the figure for the sub-regency containing Laubuluh (0.927) is the lowest in the regency—suggesting manipulation of male births, excess male mortality, or a higher male out-migration rate.

Figure 2. Doulu (top) is enclosed by steep, densely forested mountains that effectively limit the total arable land in the surrounding area; Laubuluh (bottom) is surrounded by gentile hills that are amenable to agriculture.

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 the ages of 15 and 65 years old (n=240), yielding information on their children (n=625), among whom the sex ratio was 0.953 (n=305 sons). Reproductive, marriage, child mortality, and immunization histories were collected retrospectively. Household economic information was collected cross-sectionally. All interviews were done privately in *Bahasa Indonesia* or *Bahasa Karo* with the help of trained, female research assistants.

Because of the nature of the hypotheses, only sons were included in the analyses. 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 data collection. The closing dates of IBIs in women older than 45 years old at the time of study were truncated to the date of the 45th birthday. The child of interest in these analyses was the one whose birth opened the interval. Two measures of parental investment were used. First, age-five mortality (M_5) was defined as death within the first-5 years of life, and was measured as both a binary (i.e., died or survived) and a continuous variable (i.e., age in months at death). For the continuous version, age was truncated to 60 months in older children. Second, number of immunizations, was a categorical variable with levels from 0 to 9.

There were 3 predictors of interest in this study—2 measured variables and their interaction term (see Table 2). First, the number of sons already in the sibship on the date of birth of the focal child (aka "brothers") was treated as both a dummy variable for "at least 1 brother" and a continuous covariate. Second, parental landholding (aka "land") was treated primarily as a dummy variable for "owns land" but it was also used as a continuous covariate in some analyses, measured in number of hectares owned. The interaction term was simply a multiplicative factor of the other two predictors of interest. It was used to test the hypothesis that landholding played a mediating role between brothers and the dependent variables.

A number of control variable were also included in the analyses: birth order, village, mother's education, child's age, and age-one mortality (see 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.

Table 2. Descriptive statistics for independent variables.

	n	Mean	SE
1. Birth order	250	2.268	0.082
2. Mother's age (yrs.)	250	25.516	0.353
3. Village:			
Doulu	122	--	--
Laubuluh[a]	128	--	--
4. Age-five mortality:			
Died	11	--	--
Survived[a]	239	--	--
5. Child's age (yrs):			
<1[b]	13	--	--
1-6-[c]	85	--	--
7-26[d]	139	--	--
26+[a,e]	12	--	--
6. Mother's education:			
None	2	--	--
Elementary	67	--	--
Jr. high school	62	--	--
Sr. high school	102	--	--
University[a]	12	--	--

[a] Reference category.
[b] Immunizations likely to be incomplete.
[c] Born after addition of Hepatitis B vaccine (3 doses) in 1997.
[d] Born after initiation of vaccination program in 1977.
[e] Born before initiation of vaccination program in 1977.

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 order two. Village was treated as a dummy variable for "Laubuluh." Mother's education was treated as a series of dummy variables, each indicating that she had at least some education at that level. Child's age was included as a control variable only in the immunization analyses. It was treated as a three dummy variables corresponding to the 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. Age-one mortality—death within the first 12 months of life—was treated as a dummy variable for "died" and was included only in the immunization analyses.

Statistical Analyses

Both bivariate and multivariate statistical analyses were used to address whether landholding mediates the relationship between the number of boys in a sibship on one hand, and reproductive rate (IBIs) and parental investment (M_5 and immunizations) on the other. All of the analyses were done using Stata 10. Statistical significance was set at α=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-Steffenmeister and Jones 2004; Cleves et al. 2008). These are standard methods for handling duration data with right-censoring. Survivorship functions, estimated with K-M estimates of the hazard of failure, were used to compare groups visually, and Breslow χ^2 tests were used to compare them statistically. 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 occured 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 were calculated by simply exponentiating the estimated coefficient. The HR measures the change in the hazard for a one-unit increase in the covariate. Additional statistical tools were used to test for the predicted interaction effect with the M_5 data. Probability of death and the associated odds ratios (ORs) were calculated for M_5, excluding censored cases—i.e., only children 60 months of age or older were included in the calculations. Because some cells in the contingency table had counts less than 5, Fisher's exact test was used instead of the standard χ^2 test (Agresti 2006). Bivariate comparisons of the number 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 2006; Rabe-Hesketh and Skrondal 2008). Wald χ^2 tests were used to test whether the effects were statistically significant.

The regression modeling strategy used can be described as follows: Two models were built for each of the three independent variables—one without and one with the interaction term. All models included a number of covariates chosen for theoretical reasons (see above). Because the sample included multiple children from the same sibship, it could not be *a priori* assumed that the observations were independent. For this reason, each regression model was built twice—once using standard methods, and another time adjusting for repeated measures with shared frailty models in Cox regression (Box-Steffenmeister and Jones 2004) and Guassian random-intercept models with poisson regression (Gelman and Hill 2007). Clusters were defined by the focal mother's unique identifier. For each set of models, the hypothesis that the variance parameter for the frailty and random-effects submodel equaled 0 could not be rejected (i.e., all *p*-values were >0.10). Based on this qualification, the standard models were used for inference, and observations were assumed independent.

RESULTS

Interbirth Intervals

Bivariate analyses of IBIs provided strong evidence of the predicted interaction effect. The median IBI following the birth of a son was 46 months (SE=1.659), calculated from the sample of 147 closed, and 92 right-censored, intervals (n=239). The IBIs were significantly longer (χ^2=8.31, *p*=0.004) when the sibship already contained at least 1 brother than when it contained no brothers—medians of 65 (SE=0.792) and 42 months (SE=3.988). Landowners had longer IBIs than the landless—medians of 50 (SE=1.652) and 41 months (SE=1.255)—but the difference was not statistically significant (χ^2=1.75, *p*=0.186). Figure 3 illustrates the interaction effect by comparing survivorship curves for IBI by number of brothers, stratified by landholding. The lower panel shows clear separation of survivorship functions among landowners. That is, when the sibship already contains at least 1 brother, IBIs are significantly longer (n=186, χ^2=5.97, *p*=0.003) than when it contains no brothers—medians of 75 (SE=4.989) and 42 (SE=0.791) respectively. The upper panel shows no separation for the landless. That is, there is no statistical difference (n=53, χ^2=0.25, *p*=0.618) between the IBIs of sibships that contain no brothers and those in sibships with at least 1 brother the landless—medians of 48 (SE=1.339) and 40 (SE=0.686) respectively.

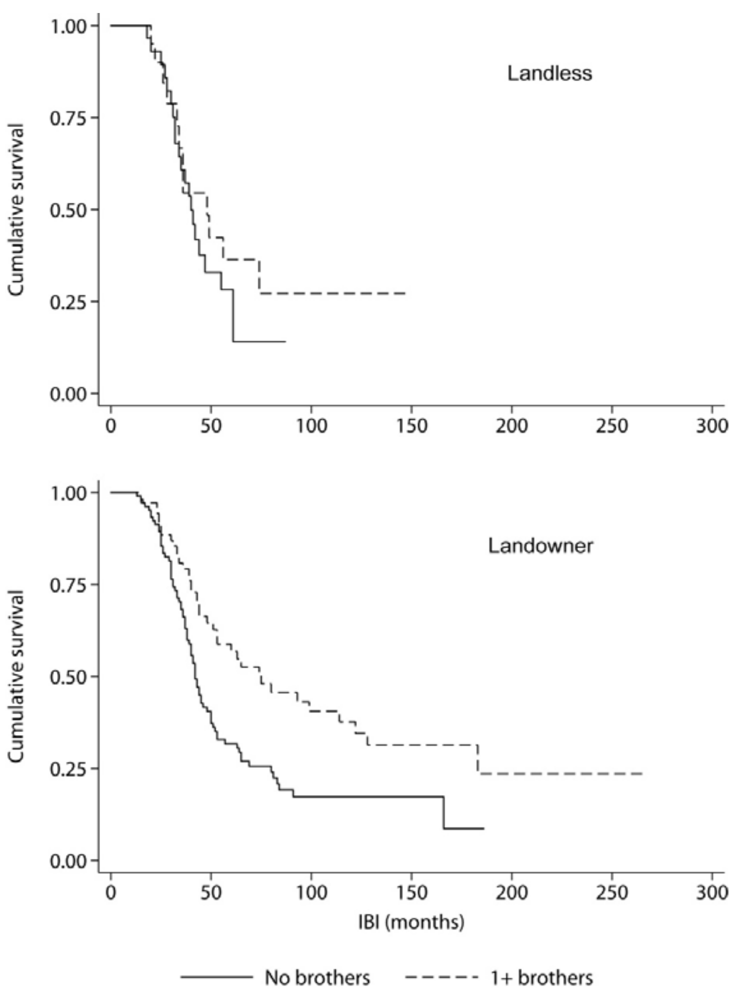

Figure 3. Observed survival functions of IBIs by number of brothers (binary coding) already in the sibship at birth, stratified by landowning status.

Cox regression models provided additional evidence of the predicted interaction effect, while controlling for birth order of the son opening the interval, village, and mother's education and age in years. Although the predicted interaction was absent from the model with binary coding for landholding, it appeared in the model with continuous coding, so only the continous version is presented in Table 3. Of the predictors of interest in the *interaction model*, both brothers (HR=1.573, *p*=0.046) and the interaction between brothers and land (HR=0.830, *p*=0.037) were substantively and statistically significant, but landholding was not (HR=1.115, *p*=0.155). This cluster of effects is presented graphically in Fig. 4 and described as follows: Among the landless and at low levels of landholding, increasing the number of brothers already in the sibship led to an increased hazard of closing the interval (i.e., shorter IBIs). The interaction term effectively reversed the relationship at higher levels of landholding. The estimated "crossover" to decreasing reproductive rates with increasing brothers occurs at 2.5 ha. To ensure that the effect was indeed linear and not curvilinear, the models were re-run with a quadratic transformation of landholding, but they revealed no statistically detectable effect.

Table 3. Cox regression models of IBIs following the birth of a son (n=233).

	HR	SE	95% CI of HR Lower	Upper	Wald	p [a]
Model A: *No Interaction* (LL=-629.9, LR χ^2=81.52, df=8, p<0.001)						
1. Birth order	0.559	0.079	0.423	0.738	-4.09	0.000 ***
2. Village:						
Laubuluh	0.538	0.094	0.382	0.759	-3.54	0.000 ***
Doulu[b]	--	--	--	--	--	--
3. Mother's age (yrs.)	0.933	0.021	0.892	0.975	-3.04	0.002 **
4. Mother's education:						
No schooling	1.347	1.384	0.180	10.095	0.29	0.772
Elementary	0.818	0.183	0.529	1.267	-0.90	0.369
Jr. high school	1.205	0.255	0.797	1.824	0.88	0.377
Sr. high school+[b]	--	--	--	--	--	--
5. Brothers	1.124	0.197	0.797	1.585	0.67	0.504
6. Land (ha.)	1.009	0.062	0.895	1.138	0.15	0.878
Model B: *Interaction* (LL=-627.7, LR χ^2=86, df=9, p<0.001)						
1. Birth order	0.563	0.080	0.427	0.743	-4.05	0.000 ***
2. Village:						
Laubuluh	0.542	0.096	0.383	0.766	-3.47	0.001 **
Doulu[b]	--	--	--	--	--	--
3. Mother's age (yrs.)	0.935	0.021	0.894	0.978	-2.93	0.003 **
4. Mother's education:						
No schooling	1.538	1.586	0.204	11.606	0.42	0.676
Elementary	0.785	0.176	0.506	1.217	-1.08	0.279
Jr. high school	1.156	0.247	0.761	1.756	0.68	0.496
Sr. high school+[b]	--	--	--	--	--	--
5. Brothers	1.573	0.357	1.008	2.455	2.00	0.046 *
6. Land (ha.)	1.115	0.085	0.960	1.295	1.42	0.155
7. Sons x land	0.830	0.074	0.697	0.989	-2.08	0.037 *

[a] Significance: **p*<0.05, ***p*<0.01, ****p*<0.001..
[b] Reference category.

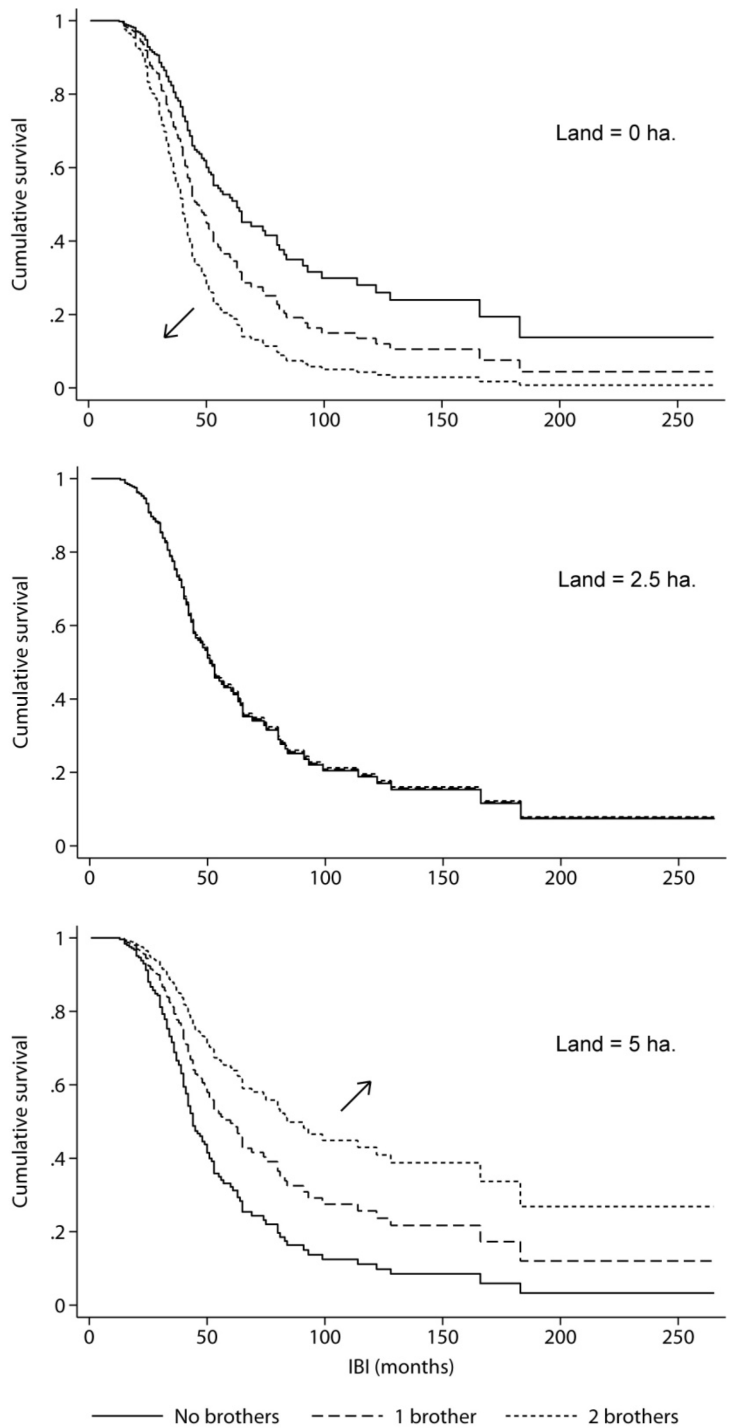

Figure 4. Predicted cumulative survival from *interaction* model, illustrating the mediating effect of land on the relationship between brothers and reproductive rate (arrows show direction of increasing number of brothers).

Age-Five Mortality

Age-five mortality among boys was analyzed using both contingency table and event history analysis. The contingency table analyses provided evidence of the predicted interaction, but the effects were not statistically significant. Table 4 presents a summary of M_5 in boys who were at least 5-years of age at the time of study. Among the landless, the odds of dying were about 21% higher in sons with at least 1 brother at the time of birth (83 deaths per 1,000 births) than in sons with no brothers (69 deaths in 1,000 births), but this difference was not statistically significant (p=0.661). Among landholders, the odds of dying were about 168% higher in sons with at least 1 brother (89 deaths per 1,000 births) than in sons with no brothers (33 deaths in 1,000 births), but this difference was not statistically significant (p=0.265). Sample size is clearly an issue with these data (i.e., there were only 11 observations of death), as the OR confidence intervals are expansive even when estimated using exact methods.

Table 4. Contingency table of observed M_5 in boys by number of sons, stratified by landowning status (excludes censored cases).

	Brothers	Age 5		Prob.	OR[A]	95% CI of OR[A]		p [B]
		Alive	Dead	(dead)		Lower	Upper	
Landless	0	29	2	0.069	1.208	0.019	25.21	0.661
	1+	12	1	0.083				
Landowner	0	90	3	0.033	2.679	0.496	17.80	0.265
	1+	56	5	0.089				

[A] Odds ratios and confidence intervals calculated using exact methods.
[B] Fisher's exact test (H_0: OR=1); 2-tailed p-values.

Bivariate analyses using event history methods provided some evidence for the predicted interaction, but it is inconclusive. The K-M estimate for survival to 60 months was 0.957 (SE=0.013), calculated from the sample that included boys who were less than 5-years of age at the time of study (n=254). Boys with no brothers at birth had greater estimated survival than those with at least 1 brother—survival estimates at 60 months of 0.976 (SE=0.012) and 0.923 (SE=0.030) respectively—but the difference was not statistically significant (χ^2=2.52, p=0.113). There was less than a 1% difference in survival to 60 months (χ^2=0.31, p=0.576) between landowners (s_{60}=0.960, SE=0.015) and the landless (s_{60}=0.952, SE=0.027). Figure 5 illustrates that although a trace of the predicted interaction is present at older ages (compare the two panels for separation of curves for "no brothers" and "1+ brothers" at 60 months), the mediating effect is absent from birth to 40 months. During that span, contrary to prediction, the bottom-panel curves for landowners have either identical, or less, separation than the top-panel curves for the landless. Nonetheless, the difference between the curves is marginally significant (n=189, χ^2=3.01, p=0.083) for landowners, but not significant for the landless (n=65, χ^2=0.19, p=0.664).

Multivariate analyses were also inconclusive. A series of Cox regression models were built to analyze survival to 60 months of age, while controlling for the child's birth order, village, and mother's education in years (see Table 5). Although the estimated interaction effects all had the predicted positive values, none of the models provided a good fit for the data. None of the global likelihood ratio tests were statistically significant. Models A and G (both excluding all control variables) were marginally significant (p=0.095 and 0.060 respectively), supporting the conclusion that the child mortality data are insufficient for multivariate analysis.

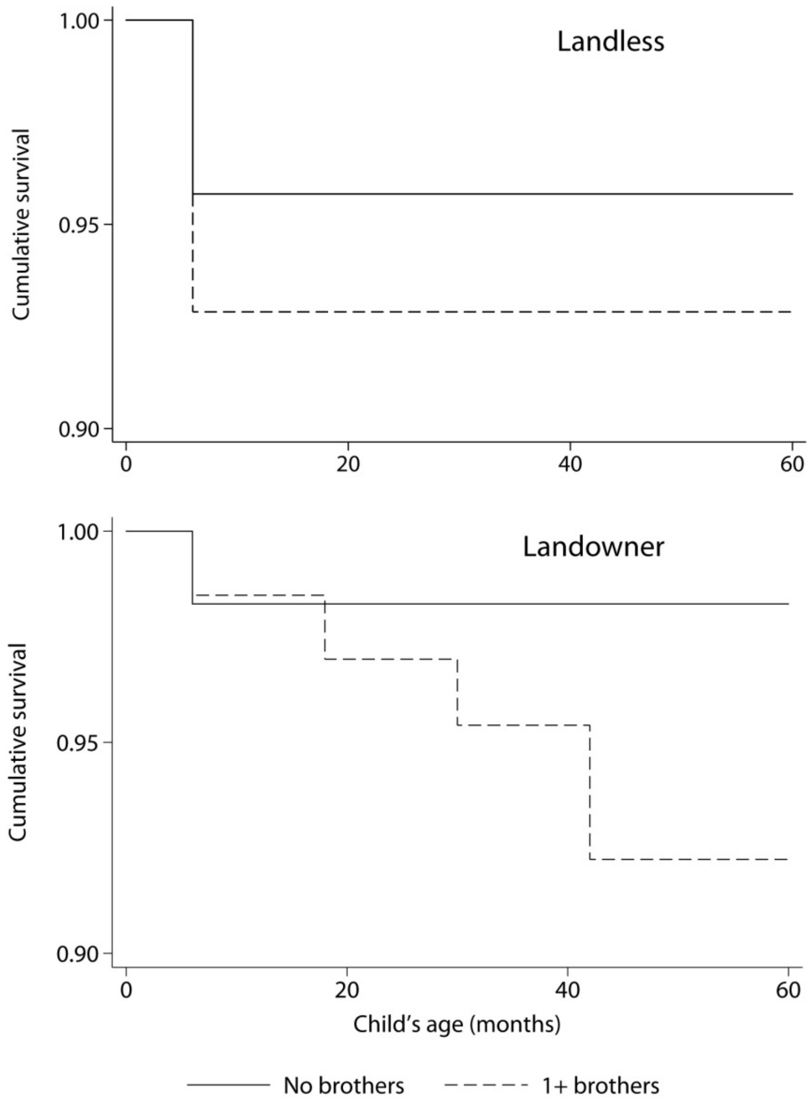

Figure 5. Observed survival of sons to 5 years old by number of brothers (binary coding), stratified by landholding.

Table 5. Cox regression models of M_5 (n=245).

Model	Land	Brothers	Controls	Interaction[a,b]			LL	LR test[b]		
				Incl.	HR	*p*		df	χ^2	*p*
A	Binary	Contin.	None	Yes	2.054	0.301	-51.4	3	5.85	0.119
				No	--	--	-51.9	2	4.71	0.095 †
B	Binary	Contin.	Birth order, village	Yes	1.727	0.431	-50.5	5	7.54	0.184
				No	--	--	-50.8	4	6.88	0.142
C	Binary	Contin.	Birth order, village, mom's educ. & age	Yes	1.884	0.364	-50.0	6	8.11	0.230
				No	--	--	-50.5	5	7.24	0.204
D	Binary	Binary	None	Yes	2.661	0.509	-52.5	3	3.67	0.300
				No	--	--	-52.7	2	3.21	0.201
E	Binary	Binary	Birth order, village	Yes	2.257	0.588	-51.3	5	6.06	0.300
				No	--	--	-51.4	4	5.75	0.218
F	Binary	Binary	Birth order, village, mom's educ. & age	Yes	2.369	0.566	-51.0	6	6.17	0.404
				No	--	--	-51.2	5	5.83	0.324
G	Contin.	Contin.	None	Yes	1.152	0.502	-51.3	3	6.07	0.108
				No	--	--	-51.5	2	5.62	0.060 †
H	Contin.	Contin.	Birth order, village	Yes	1.114	0.631	-50.6	5	7.38	0.194
				No	--	--	-50.7	4	7.16	0.128
I	Contin.	Contin.	Birth order, village, mom's educ. & age	Yes	1.145	0.545	-50.2	6	7.80	0.253
				No	--	--	-50.3	5	7.44	0.190

[a] Each model includes a no-interaction version and a version with a first-order interaction between land and brothers.
[b] Significance: † $p<0.10$.

Immunizations

Bivariate analyses of immunizations in boys provided strong evidence of the predicted interaction. The mean number of immunizations was 6.44 (SE=0.179), calculated from the sample of boys that were 12 months of age or older at the time of study (n=237). Immunizations in boys with no brothers at birth was higher ($\bar{x}$=6.70, SE=0.236) than those with at least 1 older brother ($\bar{x}$=6.14, SE=0.269), and the difference was marginally signfificant (U=5797.0, *p*=0.051). Sons of landholders received more than an entire additional immunization on average than sons of the landless—means of 6.69 (SE=0.205) and 5.67 (SE=0.335) respectively—and the difference was highly statistically significant (U=3377.5, *p*=0.001). Figure 6 presents evidence of the interaction effect with a comparison of mean immunizations by number of sons already in the sibship, stratified by landholding

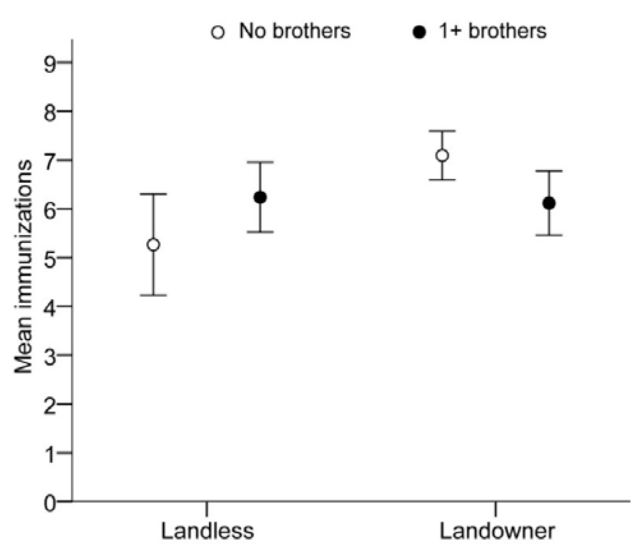

Figure 6. Observed mean number of immunizations in sons age 12 months and older with 95% CI.

status. Among the landless, there is a slight but insignificant rise in mean immunizations with a rise in number of brothers (n=51, U=264.5, *p*=0.310). Among landowners, there is a statistically significant decrease (n=185, U=3324.5, *p*=0.013).

Poisson regression provided additional evidence of the predicted interaction while controlling for the child's birth order and age, village, and mother's education in years (see Table 6). Of the predictors of interest in the *interaction model*, brothers (β=0.187, *p*=0.021), and the interaction between brothers and landholding status (β=-0.208) *p*=0.017) were statistically significant; landholding status was marginally significant (β=0.155, *p*=0.082). This cluster of effects is presented graphically in Fig. 7. The estimated mean number of immunizations increases dramatically with brothers among the landless, but decreases (albeit it, less dramatically) among landowners.

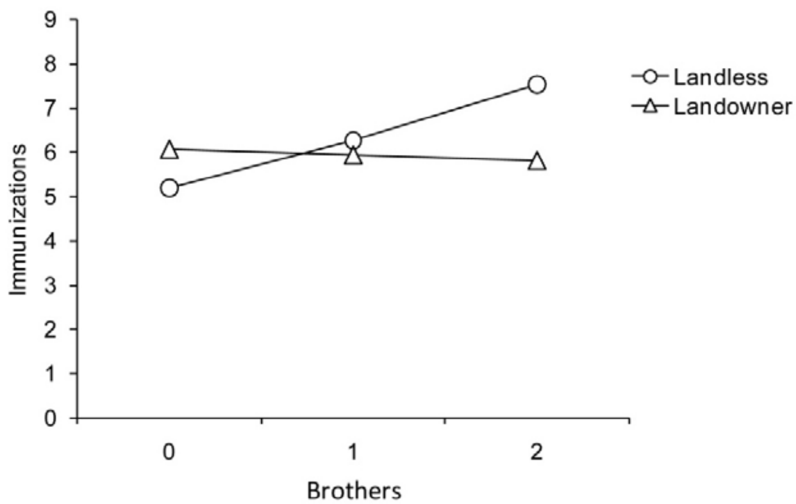

Figure 7. Estimated immunizations from *interaction* model, illustrating the mediating effect of land on the relationship between the number of brothers already in the sinship at birth of focal child and parental investment, controlling for birth order, village, and mother's education.

DISCUSSION

The analyses presented here support a resource competition interpretation of reproductive and parental strategies in Doulu and Laubuluh villages. First, reproductive rates declined with increasing sons among families with substantial landholdings, but the opposite was observed among the landless and families with small landholdings. Second, although the data are insufficient to provide conclusive evidence, there is a greater increase in child mortality (death before fifth birthday) with increasing sons among landholders than among the landless. Third, while the number of immunizations increases with increasing sons among the landless, there is a decrease among landholders. These observations mesh well with the idea that parents will 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 predicted interaction between reproductive rate (measured by interbirth intervals) and heritable wealth in land was evident. Interbirth intervals declined as a function of number of sons 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 don't we 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.

Are IBIs a good measure of investment in reproductive effort? In one sense they are; given a finite reproductive span, a 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 (*sensu* Voland and Dunbar 1995). It could also be the case, however, that the

Table 6. Poisson regression of immunizations in sons (n=235).

	β	SE	95% CI of β Lower	Upper	Wald	*p* [a]
Model A: *No Interaction* (LL=-540.3, LR χ^2=117.7, df=11, p<0.001)						
1. Intercept	1.757	0.150	--	--	--	--
2. Birth order	-0.051	0.029	-0.109	0.007	-1.72	0.085 †
3. Village:						
Laubuluh	0.344	0.060	0.227	0.461	5.75	0.000 ***
Doulu[b]	--	--	--	--	--	--
4. Child's age:						
0-11.999 mo.	-0.669	0.298	-1.254	-0.084	-2.24	0.025 *
12-83.999 mo.	0.075	0.134	-0.189	0.338	0.56	0.578
84-323.999 mo.	0.051	0.128	-0.200	0.302	0.40	0.690
324 mo.+ [b]	--	--	--	--	--	--
5. Age-one mortality						
Died	-1.990	0.449	-2.870	-1.110	-4.43	0.000 ***
Survived [b]	--	--	--	--	--	--
6. Mother's education:						
No schooling	0.026	0.298	-0.558	0.610	0.09	0.931
Elementary	-0.142	0.069	-0.278	-0.006	-2.05	0.041 *
Jr. high school	-0.056	0.064	-0.181	0.069	-0.88	0.379
Sr. high school+[b]	--	--	--	--	--	--
7. Brothers	0.020	0.043	-0.065	0.105	0.46	0.644
8. Land:						
Landowner (1+ ha.)	0.047	0.075	-0.100	0.194	0.63	0.530
Landless (0 ha.)[b]	--	--	--	--	--	--
Model B: *Interaction* (LL=-537.6, LR χ^2=123.1, df=12, p<0.001)						
1. Intercept	1.654	0.157	--	--	--	--
2. Birth order	-0.049	0.030	-0.107	0.009	-1.66	0.097 †
3. Village:						
Laubuluh	0.346	0.060	0.228	0.463	5.75	0.000 ***
Doulu[b]	--	--	--	--	--	--
4. Child's age:						
0-11.999 mo.	-0.661	0.298	-1.246	-0.076	-2.21	0.027 *
12-83.999 mo.	0.089	0.134	-0.175	0.352	0.66	0.510
84-323.999 mo.	0.064	0.128	-0.187	0.315	0.50	0.617
324 mo.+ [b]	--	--	--	--	--	--
5. Age-one mortality						
Died	-2.013	0.449	-2.893	-1.133	-4.48	0.000 ***
Survived [b]	--	--	--	--	--	--
6. Mother's education:						
No schooling	0.026	0.298	-0.558	0.611	0.09	0.930
Elementary	-0.137	0.069	-0.273	-0.001	-1.98	0.048 *
Jr. high school	-0.069	0.064	-0.195	0.056	-1.08	0.280
Sr. high school+[b]	--	--	--	--	--	--
7. Brothers	0.187	0.081	0.028	0.347	2.30	0.021 *
8. Land:						
Landowner (1+ ha.)	0.155	0.089	-0.020	0.330	1.74	0.082 †
Landless (0 ha.)[b]	--	--	--	--	--	--
9. Interaction:						
Brothers by landowner	-0.208	0.087	-0.378	-0.037	-2.39	0.017 *
Brothers by landless[b]	--	--	--	--	--	--

[a] Significance: *p<0.05, **p<0.01, ***p<0.001, † p<0.10.
[a] Reference category.

slowdown marked an increase in parental care allocated to the current offspring. It depends on how the time during that interval is used. It seems reasonable, however, that the longer IBIs observed here indicate a divestment in reproductive effort because there was also an observed concomitant decrease in two measures of parental effort (survivorship and immunizations) in the analyses.

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, 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; (2) whether the yearly marriage probability for sons varies in a similar way; and, (3) 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 2004), as could the patrilineal social structure that underlies the system itself (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 (1991, 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 (comparisons with girls were not done here), it is not a generalized preference as only certain sons benefit.

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