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The Impact of a Labor-saving Technology on Fertility in Rural Ethiopia

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Abstract

Across the developing world labour-saving technologies introduce considerable savings in time and energy that women allocate to work. Clinical hormonal studies on natural fertility populations predict that such a reduction in energetic expenditure can lead to improved energy balance and higher reproductive function. This bio-demographic study is designed to identify whether these physiological changes do affect fertility at a population level by focusing on a recent water supply scheme in Southern Ethiopia. The demographic consequences of a reduction in women's workload following the installation of water points, specifically the variation in length of first birth interval, are investigated. First birth interval length is closely linked with lifetime fertility in non-contracepting populations, longer intervals being associated with lower fertility.

Using life tables and multivariate hazard modelling techniques correlates of the length of first birth interval are identified. Co-variates including age at marriage, season of marriage, village ecology, and access to improved water supply influence the timing of the first birth. When entered into models as a time-varying co-variate, access to the water taps is associated with an immediate increased probability of birth.

Introduction

Labor-saving technologies aim to improve women's welfare and alleviate poverty by reducing the time and energy expended on household chores. While the socio-economic costs and benefits of these intervention schemes have been well documented (Bryceson and Howe 1993; Carr 1985) surprisingly few studies have investigated the demographic effects of energy and time budget alteration. This study will examine the fertility-related changes following one significant energy-saving event, water point installation in a rural community in Southern Ethiopia.

Intra-populational studies of reproductive ecology indicate that maternal age and energetic factors explain the greatest part of observed variation in fertility for non-contracepting populations (Wood 1994). However, while age patterns are extremely robust across populations, responses to energetic stresses arise as correlates of local ecology. Effects are mediated by variation in nutrition and workload (Cumming 1990; Ellison 1993; Ellison et al. 1986; Rosetta, 1996) pattern of childcare (Huffman 1987; Panter-Brick 1989) and disease load (McFalls and McFalls 1984; Pennington and Harpending 1991; Wiley 1998).

The relationship between physical workloads and reproductive function has primarily been studied using clinical hormonal data. These have focused on the effects of reduced energy balance (weight loss) associated with the combined effect of high workloads and low nutritional reserves on fecundity (Bailey et al. 1992; Ellison et. al. 1989; Panter-Brick et al. 1993). There is some evidence to suggest that alterations in energy expenditure alone may influence ovarian function independent of weight loss (Beitens et al. 1991; Shangold et al. 1979). In a study of Polish farm workers (Jasienska and Ellison 1998) found women incurring the highest seasonal workloads experienced relatively lower rates of ovarian function, although none of them were nutritionally stressed or had lost weight during the period of work. Although such short term effects of high energetic expenditure in compromising reproductive function have been explored, the long-term chronic effect of *reduced* energy expenditure under conditions of low nutrition on fertility determinants is less well understood.

Water development technologies, which introduce savings in time and energy that women allocate to water collection, are associated with considerable improvements in women's energy budget. In rural Arsi, Southern Ethiopia, women undertake long and arduous trips to collect water. Women are required to walk between 3-6 hours per day to find water sources up to 30km away. Water-carrying loads are 20-25 liters, equivalent to up to 50% of the average women's body mass. Since the introduction of water taps in some villages, the time women spend on daily water collection has reduced (Table 1), and the time freed up is generally spent in more resting and sleeping (Allen and Earl 1997). Assuming that the time and energy saved is not diverted to other energetically costly activities and nutritional levels remain constant, water development is expected to have a positive effect on women's energy balance and hence fecundity.

Beyond the physiological effects of improved fecundity, other behavioral changes associated with water development may alter fertility, such as marriage patterns and age at first intercourse. For example, since teenage girls play an important role in household water collection, families may have less need for them at home, subsequently arranging their marriage at an earlier age. Kramer and McMillan (1998; 1999) have indicated that access to labor-saving technology in rural Mayan village is associated with an initial drop in age at first birth following changes in girls' decision-making about when to leave home. They found no effect on later birth interval lengths. However, due to constraints of the data available to them they were unable to control for secular trends in fertility. In this study the improved access to water is a recent event and it has been possible to pinpoint the month of arrival of the water point (March 1996). By entering this event as a time-varying co-variate in an event history analysis, it is possible to seek demographic change at the exact point for each woman in the analysis. Furthermore, other villages without improved water supply can serve as a proxy for conditions prior to development.

The focus of the study is to detect any effects that improved access to water supplies has on the timing of the first birth. The first birth interval is an important predictor of lifetime reproductive outcome, since it effects subsequent birth-spacing and child-bearing pattern (Bumpass et al. 1978; Trussell and Menken 1978). Examining the dynamics involved in the timing of this event has important implications for changes in family sizes occurring across the developing world. Previous demographic studies have contributed to knowledge of the pattern of first birth interval through the analysis of socio-demographic variables, for example, age at marriage, maternal age, education and living arrangements (Fricke and Teachman 1993; Nath et al. 1999; Nath et al. 1993), without examining any effects of energetic stresses, specifically nutrition and workload, on first birth interval length. By combining the use of demographic techniques with theoretical models developed in reproductive and evolutionary ecology, this study is an attempt to describe and explain patterns in first birth interval length arising from labor-saving intervention technologies.

Data and study site

Anthropological and micro-demographic data used in this research were collected by the principal author during nine months of fieldwork in the Hitosa/Dodota *woredas* (sub-districts), Arsi Province, Southern Ethiopia during 2000. This site is situated within a region of subsistence agro-pastoralism known to suffer from acute and regular water shortages. Mean annual precipitation is less than 700mm and there are no perennial rivers. Since 1996 a large-scale water supply project (Hitosa Gravity Water Supply Scheme) has been operational in some of the villages within this region. One of the major objectives of this project has been to reduce both the physical stress and the time spent collecting water for women by making clean water available at reasonable distances (less than 100-500m). Prior to water point installation the journey time to collect water ranged between 3-4 hours, and in some cases up to 6 hours for a round-trip; however, since tap installation journey times have been reduced to less than 1 hour. The region has also benefited from a local road-building project, designed to facilitate the construction of the water supply scheme, which has provided improved access to schools, clinics and markets in the nearest towns.

This region is populated by two groups of Oromo agro-pastoralists, the Arsi and the Shoa Oromos. Traditionally the indigenous Arsi Oromo were nomadic cattle-herders, however, following the immigration of Shoa Oromo cultivators into the highland areas during early 20^{th} Century, the Arsi Oromo began to settle and cultivate the dry savannah in order to compensate for losses to their cattle economy (Selinus et al. 1971). Today the subsistence economy of the entire region is based on crop production (wheat, barley and maize). Cattle herding is still prevalent, playing a central role in Oromo cultural life; cattle are the primary unit of exchange at marriage. However, over the last decade cattle numbers have declined, as grazing land has become scarce. The two groups have maintained strong separate cultural identities centered around their differing religious beliefs; Arsi Oromo are Muslim and the Shoa Oromo are Orthodox Christian.

Seven villages within this region were surveyed, which included 3 villages with access to water points and 4 villages currently without tap installation. Selection criteria for these villages included comparability of size, altitude, ethnicity and religion, facilitating comparative analyses both within and between villages (Table 1). A broad single round demographic survey was completed in 1574 households, providing data on major socio-economic and behavioral factors (e.g. number of livestock, educational levels, village residence patterns) that may influence demographic processes. A full retrospective birth history was collected from 1460 ever-married women (<50 years) within these households, including a more detailed section concerning the timing of reproductive events (including duration of marriage, births and child deaths) over the 6 years preceding the interview. These life history events were dated to the year and the month (Sept. 1993 – interview month, 2000) through the use of a calendar of local events, such as the water point installation, religious festivals (like Orthodox Christmas, Eid-ul Fitr), political events, and agricultural seasons. During the survey anthropometric measurements (height, weight, triceps skinfold thickness) were collected from a sub-sample of these women (n=434) during the dry (harvest) season.

For the purposes of this analysis the data set was limited to women who had experienced a first marriage during the observation period (since Sept. 1993) (n=366). This included both those women who had experienced at least one birth and those cases in which a woman had not experienced a first birth at the time of interview (right-censored). All women including those known to be practicing any method of family planning at the time of interview were included, based on the assumption that family planning would not have been used during the first birth interval. Contraception prevalence is extremely low in this region where cultural views are pronatalist and there is limited access to clinics and schools (0.9% of the women had ever used any method of family planning). Childbearing is closely tied with women's social identity and household status and the first birth provides evidence of a woman's fertility, assuring her position within the household.

Analytical methods

For the purposes of these analyses the dependent variable is the risk of having a first birth after marriage for all ever-married women in the sample. Discrete-time methods of event history analysis, using logistic regression to estimate the multivariate model, are employed in the analyses since the dependent variable involves a single destination state, a live birth (Allison 1984). These methods estimate the effects of the predictor variables on the probability (or logit) of an event's occurring while making no assumptions about the shape of the hazard function. The probability is based on the number of events occurring in the risk set composed of all person-periods under observation at that time.

Probability of birth per unit time:

$$P_i = X_i \beta / (1 + \exp (X_i \beta))$$

X_i = vector of co-variates for the $_i$th woman

β = vector of regression co-efficient

Using a multivariate hazards model it is possible to assess the partial effects of several factors on the length of the first birth interval. The exponentiated value of the regression co-efficient, exp(β) represents the relative risk of other groups in relation to the baseline group. Exp(β) becomes unity when there is no effect of the co-variate, with values greater (or lesser) than unity indicating that the relative risk of having a first birth interval is greater (or less) for this group than that of the reference group.

In these analyses each woman contributes an observation for every month after marriage in which no birth took place, her experience is excluded from the risk set either after a birth occurs or after the experience is censored by the survey month or by the termination of marriage. A new exploded data set is created consisting of all person-months of marriage without a birth. Each month is coded as a dichotomy: 0 if no birth occurred and 1 if a birth occurred in that month and as such multivariate equations are estimated through logistic regression (Proc LOGISTIC in SAS).

The greatest problem encountered in using birth interval data obtained from retrospective surveys relates to the incompleteness of women's maternal histories, the issue of censoring bias. Censoring arises when observations that are begun but not completed during the study period. For example, a woman is married, but the exposure period is truncated by the date of the survey, before the first birth. Ignoring this censoring bias may lead to the period of exposure being underestimated. Event history analysis is able to incorporate such cases, by including information about their survival up to the time of censoring without making an assumption about the timing of the event's occurrence in the future (Yamaguchi 1991).

Time-varying co-variates:

The use of time-dependant co-variates, namely the timing of the water point installation and function, is an important feature of this present analysis. Unlike standard forms of regression, event history analysis can be deal with this kind of duration data (Yamaguchi 1991). It is possible to examine whether the change in the state of the co-variate (function of the water point) influences the hazard rate/risk of experiencing a dependent event (first birth). In this set of analyses a new dichotomous co-variate 'water access' is created for each women; each person-month of marriage without birth is coded as either: 0 if it occurs before (or <9months after) and 1 if it occurs 9 months after water taps were installed in that women's village. In villages which had no water taps installed up to the reference survey date, this variable was coded '0' for the entire observation period.

In addition, controls for time and time squared were entered into the models for analyses, since the risk of giving birth is likely to vary as a function of length of exposure.

Other independent co-variates:

Water carrying workload

In this region 10% of women collect and carry water on their backs without assistance from either kin or donkeys. If workload effects length of first birth interval then method of water collection is likely to explain some of the variation between women. The dichotomous variable 'water carrier' has been created as a proxy for the women's water-carrying workload, classified according to whether each women exclusively carries water on her back (1) or is assisted by kin or donkeys in carrying the load (0).

Religion/Ethnicity

These villages are populated predominantly by two ethnic groups: the indigenous Arsi Oromos, Muslim agro-pastoralists inhabiting the lowland areas and Shoa Oromos, Orthodox Christians engaging in farming in the highland areas. For the present analysis the variable for religion is used as proxy for ethnic grouping, since ethnicity and religious beliefs are analogous (0= Muslim Arsi Oromo, 1=Orthodox Christian Shoa Oromo). Table 1 outlines the predominant religion of each of the villages included in the analysis.

Village ecology

The 7 villages included in the study are located in two ecological zones (Table 1), which may influence fertility levels. (1) Dry *lowland* areas subject to high temperatures and low and irregular rainfall, land degradation and soil erosion. In these villages maize is the predominant crop type and settlements consist of scattered homesteads. (2) *Highland* areas, with moderate rainfall and temperatures, maintain a subsistence economy based on wheat production. Highland settlements have a well-defined centralized village structure (laid out in a rectangular grid pattern). However, for the purposes of analysis a variable for each village is entered separately into each model to control for any unobserved socio-ecological variation between them.

Mother's education
Educational attainment across these villages remains relatively low, especially among women (87.3% of all women have never received any form of schooling). For the purposes of analysis a binary variable, mother's educational level, describes whether a mother had received any level of formal education (0=no education, 1=any school education).

Socio-economic status
Despite recent improved access to the market economy, level of socio-economic differentiation remains very limited. In this context measures of socio-economic status used in other studies, based on household items and dwelling characteristics, were inappropriate. Number of cattle, is used as a proxy for household economic status, categorized as three groupings: low status (= no cattle), medium (= 1-5 cattle) and high (= 6+ cattle).

In the research presented here current status co-variates such as mother's education, number of cattle were assumed to be invariant over the last 6 years. In this traditional society, female education is extremely rare and is unlikely to continue beyond marriage. Furthermore, within a rural subsistence based society, the economic condition of any household is unlikely to fluctuate drastically over such a short period of time.

Age at marriage
To investigate the effect of age at marriage on the first birth interval, women are classified into four age-at-marriage groups: (1) <= 14 years (2) 15-16 years (3) 17-18 years (4) >= 19 years.

Polygyny
Polygyny is common in this region, particularly among the Muslim population (25% of women are in a polygynous marriage in total population) and is another factor likely to influence birth spacing. In the analysis women are classified according to their husband's current marital status (0=one wife, 1=more than one wife).

Marriage cohort
To control for any historical secular trend in the data, which spans 6 years, a co-variate, marriage cohort, is included in the analysis. Marriage cohort is categorized according to year of marriage (1) 1993-94 (2) 1995 (3) 1996 (4) 1997 (5) 1998 (6) 1999-2000.

Seasonality
A binary co-variate to describe marriage season, is included in the analysis to control for any effects of seasonality that may affect first birth interval length. Although women do not work heavily in the fields, seasonal changes in subsistence ecology relating to other

workloads, food availability and disease may impact on fertility. The dry season is defined as the harvest/ post harvest season (October-April). The wet season covers the period between the first rains in May up to the end of the long rains and early harvest around New Year in September (0=dry season, 1=wet season).

Maternal nutritional status

To control for the effect of women's nutritional status on length of first birth interval, body mass index (wt/ht^2) (BMI), is calculated for the sub-sample of women that were included in the anthropometric survey (n=107) during the post-harvest season. In general this sample of recently married women have a normal BMI (>18.5); the mean BMI is 20.51 SD 2.05.

Although the BMI for each woman is unlikely to have remained constant over the entire observation period (e.g. fluctuating between seasons), this current status measure, broadly categorized, may be used as an overall indicator of variation between women. Body mass indices are categorized into three groups based on the recommendations of (Ferro-Luzzi et al. 1992) low nutrition (= <18.5), moderate level of nutrition (= 18.5-22), and high level of nutrition (= >22).

Results

Using univariate life table techniques, which incorporate both uncensored and censored lengths of birth interval, it is possible to calculate median first birth interval length (estimated from the survival function) by different characteristics to give a quick comparison of the variability in first birth interval length. Table 2 presents a summary of median birth intervals and the percentage of women who failed to give birth within the first 48 months of their marriage for groups of co-variates included in the final analysis. The overall median length of the first interval is 14.80 months, while only 2.64% of the women failed to give birth within 48 months of their marriage.

To test for significant differences in the survival functions of the first birth interval between groups a non-parametric Wilcoxon statistical test is used, since some of the variables are not normally distributed. Age at marriage, village altitude and marriage season are all statistically significant. These results suggest that women who marry at a young age have longer first birth intervals than later married women. When grouped as such, women from the highland villages have shorter birth intervals than women residing in lowland villages. Generally, women married during the wet season experience shorter intervals than those married in the dry season. The analysis suggests that none of the socio-economic or nutritional status variables play a significant role in explaining first birth interval in this population.

Table 3 presents median values estimated from the survival function for age at marriage, age at first birth, and length of first birth interval between villages according to water accessibility across the observation period. Median values are calculated for groups of women first married before and married after March 1996, the date of water point installation. The results suggest that within those villages benefiting from improved water supplies, a number of demographic changes have occurred. Since water taps were installed, age at first marriage and subsequently age at first birth have increased. While lengths of first birth intervals have also shortened; this result becomes statistically significant only once one lowland village suffering recent crop failures (Debula Saapo) is removed from the analysis. However, in those villages which continued to use traditional water supplies across the entire observation period, there has been no trend towards increasing age at marriage or age at first birth, and no significant change in the length of first birth interval.

For additional analyses, hazard regression models were estimated using two different specifications to directly assess the effects of water point access on length of first birth interval after controlling for other factors. The models describe the observed and multivariate results of the analyses in the form of exponentiated coefficients for the log odds. Coefficients are converted into an odds ratio relating the presented effect to the omitted category by calculating Exp(B) for each coefficient in the original equation (dummy variable logistic regression). Each model presents the effects of each variable, controlling for all the other variables in the model.

To test the assumption of proportional hazards a separate model was run (not shown here) to explore any interactions effects between time (length of exposure since marriage) and the water point installation. There was no significant level of interaction, indicating that the assumption of proportional hazards is valid (water*month, p=0.319). Similarly there were found to be no significant interactions between current nutritional status and time or between any other independent variables. However, the positive coefficient for time (months) and the negative coefficient for time squared in all models indicates that risk of first birth has a 'U'-shape relationship with time (months since marriage). These may relate to coital frequency, gestation length, foetal loss and fecundity (Wood 1994).

Table 4 contains result of the analysis using a discrete time logistic regression model of the effects of socio-demographic variables, water point installation as a time-varying co-variate and a dichotomous co-variate to define method of water collection (Model 1). Table 5 introduces a co-variate to control for women's current nutritional status, body mass index, (Model 2) in which the sample size is reduced (n=107).

In both the models described above, observed relationships suggest that women who marry at a higher age (>17) have a higher risk of childbirth than those marrying at younger ages. Women married at <15 years of age are about one-third less likely than women in the following age group (15-16) to experience a birth per month following marriage. Figure 1 illustrates the effect of age at marriage on mean completed first birth interval length. However, in Model 2, after including the nutritional status co-variate, the effect of maternal age at marriage becomes insignificant, which may be an artifact of the reduced sample size or implies that the effect of age on birth interval length is mediated through women's nutritional status.

The effect of village on first birth interval confirms the expectation that ecological conditions associated with altitude would have an effect on fertility differentials. The observed effect reveals that women living in the two lowland villages are almost 50% less likely to experience a birth per month. It is these lowland villages (particularly Debula Saapo) which have suffered the chronic effects of repeated crop failure in recent years. Figure 2 illustrates the effect of altitude on risk of birth per month.

There is some evidence to suggest that there has been a decline in first birth interval length across all villages over the study period (since 1993) (Table 3). However, the results from the hazards model suggest that only women married the year before water point installation have a significantly altered risk of birth. These women have a lower risk of experiencing a birth in the months that followed marriage than the reference group (1996, the year of tap installation).

Season of marriage is also associated with probability of childbirth; women married during the wet season (May-Sept) are at a higher risk of birth per month than women married during the dry season. This season is associated with low water-carrying workloads, as local groundwater is collected, and improved nutrition, as milk products are readily available due to effects of rainfall on cattle reproductive ecology. This effect of marital season disappears in Model 2, which may be related to the reduced sample size or may suggest that the effect of season on first birth interval length is mediated by nutritional status.

Relationships between the first birth interval and measures of social and economic status are not observed. Religion, marital status (presence of polygyny), maternal education and number of household cattle have no independent effect on rate of childbearing. There is some suggestion of a trend in towards a lower risk of birth per month for categories reflecting higher socio-economic status (woman's access to formal education, household herd size), however this effect is not significant.

Women who exclusively carry water on their backs are at a lower risk of first birth in each interval than women who are assisted by kin and/or donkeys. Women water carriers are almost 50% less likely to experience a first birth in each month following marriage. This co-variate is likely to be a reliable measure of energetic workload and not socio-economic status of the household, since the effect of water carrying is working in opposite direction to other socio-economic determinants (in which higher status is associated with lower risks of birth).

In Model 1 it can be seen clearly that there is a positive effect of water point installation on monthly risk of childbirth. The results suggest that improved access to water at any point since marriage almost doubles women's risk of having a first birth per month. A Kaplan Meier plot (Figure 3) clearly illustrates this increased risk following improved water supplies recording monthly survival functions for two marital cohorts, grouped by marriage date before or after water tap installation (excluding village Debula Saapo). In Model 2 the inclusion of nutritional status into the analysis reveals that body mass index has no significant effect on the first birth hazard, while the effect of the water point remains significant.

Conclusions

Using life tables and multi-variate hazards analysis this study identifies a number of social and biological co-variates of first birth interval associated with access to a new water supply scheme. Changes in two key reproductive events are observed in response to the introduction of water points, which are absent in adjacent villages without access to new water sources.

Firstly, mean age at marriage (and age at first birth) has increased. This finding is the opposite of the effect observed by Kramer and McMillan (1999) among the Maya, where median age at first birth dropped following labor-saving technology. The shift towards later age at marriage is likely to be related to social development occurring in these villages associated with the water supply scheme, most notably the construction of roads has provided improved access to the market and schools.

Secondly, median length of first birth interval has reduced since 1996 when taps were installed. This association does not necessarily indicate that the decline in birth interval length is causally related to an improvement in women's workloads, but may be an effect of later age at marriage or change in other co-variates. Adolescent subfecundity may be present in this population, since birth interval length varies by age at marriage, with young women married <15 years experiencing an unusually long first birth interval. This period of adolescent subfecundability is known last for up to 2 years following menarche (vom Saal and Finch 1994). The results of a multivariate hazards analysis model demonstrate that after controlling for secular trends in socio-demographic variables, the introduction of the water point is still associated with a significantly increased risk of birth per month. Furthermore, the finding that women water carriers are exposed to lower risks of birth per month than those assisted by donkeys and/or other kin, indicates that the energetic effect of workload is enough to influence fertility.

Other studies have highlighted the effects of nutritional status on the duration of the birth interval; undernutrition is associated with delaying reproductive maturation (Foster et al. 1986) and risk of intrauterine mortality (Ford et al. 1989). The results of the second multi-variate hazards model suggest that maternal nutritional status does not predict monthly risk of birth for this sample of women. This adds to a growing body of research suggesting that the effects of subtle forms of undernutrition may not influence fertility (Delgado et al. 1982; John et al. 1987; Strassman and Warner 1998). Similarly, there is no evidence to suggest that access to improved water supply has improved early child or intrauterine mortality (Gibson in prep).

Overall these results suggest that the reduction in workload has increased first birth interval length independent of other socio-demographic changes associated with the installation of taps. Since the timing of first birth determines the pace of later birth scheduling and bears a negative relationship with family size in non-contracepting populations (shorter first birth intervals being associated with higher fertility), improved water supply may result in unforeseen population growth. Awareness that such demographic changes could occur might influence both the behavior of users and the nature of services offered in future intervention.

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Table 1: Socio-ecological characteristics of 7 villages

Village	n	Altitude (m.a.s)	Predom-inant religion	Journey time to collect water before 1996*	Journey time to collect water after 1996*	Access to taps**
Daya Debeso	54	High 2000m	Christian	6 hours	<30 minutes	Yes
Daya Gabrel	70	High 2000m	Christian/ Muslim	6 hours	<30 minutes	Yes
Terro Moyee	45	High 1960m	Muslim	4-6 hours	4-6 hours	No
Hurturbe	44	High 1980m	Muslim	4-6 hours	4-6 hours	No
Reissa Michiko	57	Low 1880m	Christian/ Muslim	3 hours	3 hours	No
Debula Saapo	46	Low 1800m	Muslim	6 hours	<30 minutes	Yes
Bekare Washo	46	Low 1800m	Muslim	3 hours	3 hours	No

Notes: n= sample number of ever-married women (<50)
* during height of dry season (Dec-Apr); local ground water is collected in wettest months
** at time of interview

Table 2: Median survival time of first birth interval (months) for specified covariates

Covariates	Median	n	Wilcoxon (p)	% with no births within 48 mths or up to censoring
Overall	14.80	366		2.64
Marriage cohort			0.289	
1993/94	15.50	58		0.00
1995	16.33	54		3.13
1996-water	14.00	66		6.06
1997	14.50	53		0.00
1998	13.75	55		11.81
1999/2000	15.34	70		10.74
Age at marriage			0.002**	
<15	18.90	37		7.58
15-16	15.49	175		3.54
17-18	13.46	105		0.00
>=19	13.81	49		0.00
Marriage season			0.055**	
Wet (Jun-Sep)	15.64	222		3.79
Dry (Oct-May)	14.10	144		1.04
Village			0.000**	
Lowland	17.20	152		4.56
Highland	13.85	214		1.42
Religion			0.822	
Muslim	14.76	253		3.06
Orthodox christian	14.96	113		1.52
Polygyny			0.302	
Only wife	14.94	332		2.85
One of several	13.92	34		0.00
Women's education			0.269	
No education	14.94	278		3.47
1 years +	14.43	88		0.00
Herd size			0.283	
No cattle	15.73	164		2.40
1-5 cattle	14.22	162		1.10
6+ cattle	17.19	40		8.61
Water carrier			0.639	
Alone on back	14.92	35		6.22
With help	14.79	331		2.06
Body Mass Index			0.684	
<18.5	13.33	17		0.00
18.5-22	14.46	71		1.53
>22	17.25	19		8.40

**p=<0.05

Table 3: Variation between villages since the arrival of water taps (March, 1996) for mean age at marriage, median age at first birth and median length of first birth interval.

	Date	Village Access to Water					
		Without water points		With water points (all)		With water points (excluding Debula Saapo)	
Mean age at marriage	Before 1996	16.45	n=100 SD1.93	15.93	n=74 SD1.79	15.84	n=60 SD1.75
	After 1996	16.68	n=95 SD2.03	16.92 **	n=97 SD2.09	16.92 **	n=64 SD2.09
Median age at first birth	Before 1996	17.60	n=99	17.23	n=73	17.16	n=59
	After 1996	17.68	n=57	17.97 **	n=71	17.90 **	n=46
Median first birth interval	Before 1996	15.60	n=100	14.83	n=74	14.75	n=60
	After 1996	14.18	n=95	14.48 *	n=97	12.74 **	n=64

* * Wilcoxon test (p=<0.05), Mann Whitney U test (p=<0.05)

*   Wilcoxon test (p=<0.1)

Table 4: Multi-variate hazard regression model for first birth interval (Model 1)

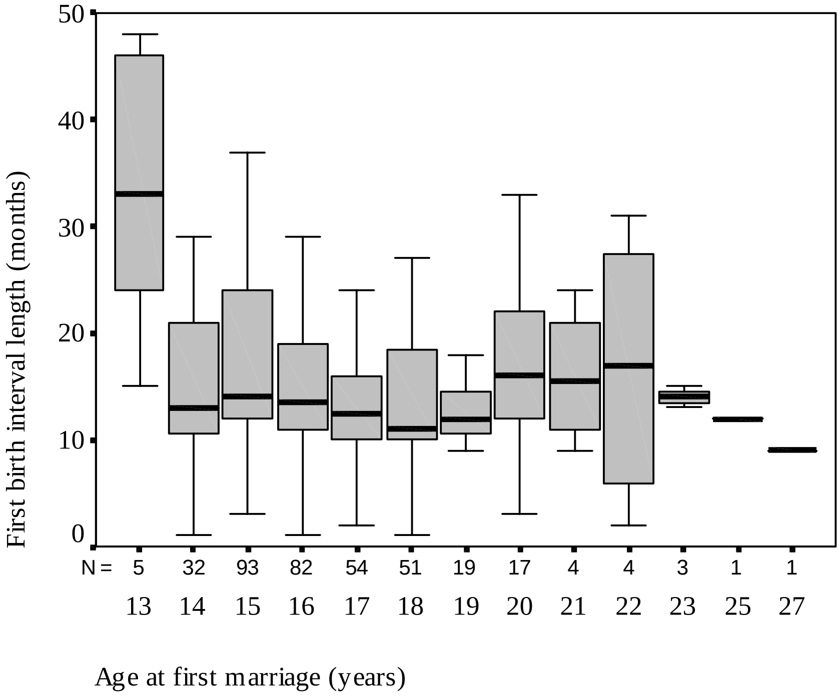
Variable	Odds ratio	P
Marriage cohort:		
1993-94	1.006	0.979
1995	0.674	0.054*
1996	1.000	-
1997	0.726	0.132
1998	0.895	0.604
1999-2000	1.127	0.689
Age at marriage:		
<15	0.668	0.096*
15-16	1.000	-
17-18	1.417	0.024**
>=19	1.118	0.593
Marriage season:		
Dry	1.000	-
Wet	1.381	0.020**
Villages:		
D.Debeso	0.825	0.631
D.Gabrel	0.841	0.610
T. Moyee	1.000	-
Hurturbe	1.412	0.180
R.Michiko	0.702	0.170
B.Washo	0.558	0.023**
D.Saapo	0.369	0.004***
Religion: Muslim	1.000	-
Christian	0.850	0.467
Polygyny: No	1.000	-
Yes	1.095	0.695
Mother's education:		
None	1.000	-
>=1year	1.104	0.566
Cattle (no.)		
None	1.000	-
1-5	0.910	0.547
6+	0.670	0.106
Water carrier: No	1.000	-
Yes	0.718	0.092*
Water point installation:		
Without access	1.000	-
With taps	1.873	0.027**
Time	1.432	0.000***
Time sq	0.993	0.000***
Intercept (Coefficient)	–6.098	0.000***
Total cases (months)	6236	
Births (n)	297	

Note: Reference category has odds ratio of 1.000
*p=<0.1, **p=<0.05, ***p=<0.005

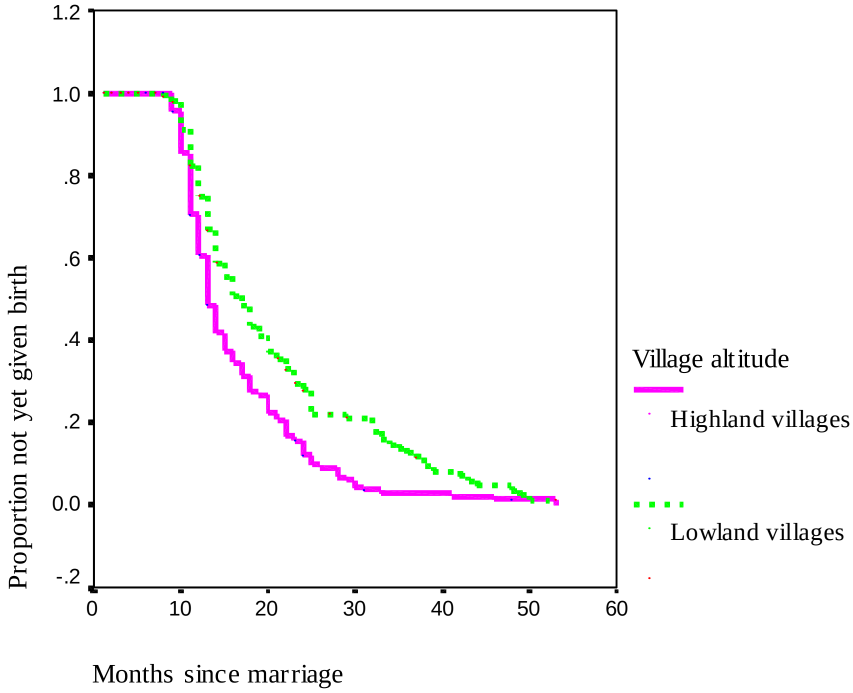
Table 5: Multi-variate hazard regression model for first birth interval (Model 2)

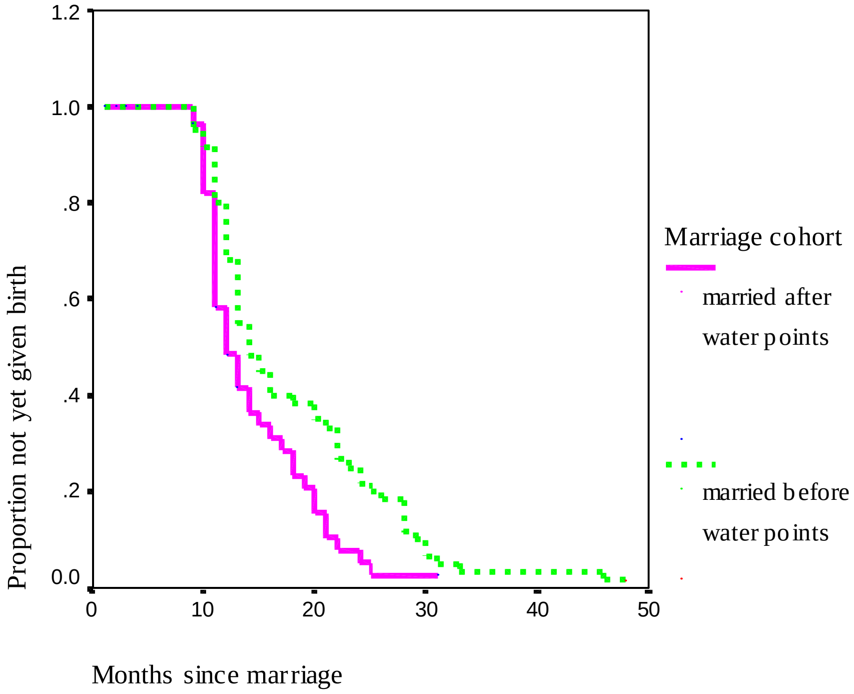
Variable	Odds ratio	P
Marriage cohort:		
1993-94	0.814	0.654
1995	0.249	0.005***
1996	1.000	-
1997	0.959	0.931
1998	0.766	0.519
1999-2000	0.790	0.728
Age at marriage:		
<15	0.546	0.240
15-16	1.000	-
17-18	0.754	0.470
>=19	1.469	0.319
Marriage season:		
Dry	1.000	-
Wet	1.043	0.875
Villages:		
D.Debeso	0.649	0.604
D.Gabrel	0.331	0.151
T. Moyee	1.000	-
Hurturbe	1.504	0.419
R.Michiko	1.027	0.961
D.Saapo	0.144	0.011**
Religion: Muslim	1.000	-
Christian	0.530	0.181
Polygyny: No	1.000	-
Yes	1.553	0.359
Mother's education:		
None	1.000	-
>=1year	0.664	0.287
Cattle (no.):		
None	1.000	-
1-5	0.506	0.038**
6+	0.503	0.214
Water carrier: No	1.000	-
Yes	0.442	0.060*
Water point installation:		
Without access	1.000	-
With taps	3.621	0.016**
Body Mass Index		
<18.5	1.607	0.214
18.5-21.5	1.000	-
>=21.5	0.706	0.345
Time	1.588	0.000***
Time sq	0.991	0.000***
Intercept (Coefficient)	-5.981	0.000***
Total cases (months)	1763	
Births (n)	94	

Figure 1: Mean length of completed first birth interval by age at marriage
Figure 2: The effect of village altitude on risk of first birth
Figure 3: Probability of experiencing a first birth for two marital cohorts in villages with access to water (women married before vs. after tap installation)



First birth interval length (months)
50
40
30
20
10
0
N = 5 32 93 82 54 51 19 17 4 4 3 1 1
13 14 15 16 17 18 19 20 21 22 23 25 27
Age at first marriage (years)


1.2
1.0
.8
.6
.4
.2
0.0
-.2
0
10
20
30
40
50
60
Proportion not yet given birth
Village altitude
Highland villages
Lowland villages
Months since marriage



1.2
1.0
.8
.6
.4
.2
0.0
0
10
20
30
40
50
Proportion not yet given birth
Months since marriage
Marriage cohort
married after water points
married before water points