Social and Ecological Drivers of Birth Seasonality in Sub-Saharan Africa

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Abstract

Seasonal fluctuations in births are ubiquitous in human populations, however the causes are not well understood. Researchers in different disciplines have each postulated on potential drivers of human birth seasonality. Human evolutionary biologists have looked at the role of seasonal fluctuations in food availability and seasonal fluctuations in light intensity; economist have focused on the role of seasonal fluctuations in labor demand; while sociologists have focused on social factors such a religious holidays and marriage time preference. Still others have looked at the role of temperature. Simply stated, the birth seasonality research has been fragmented. In this paper we present the background and mechanisms behind each set of potential drivers of birth seasonality. Next using a novel methodology and data from the Demographic and Health Surveys that are spatially joined with observations from ERA-Interim, a re-analysis of historical data from weather stations using state of the art models, we are able to test the relative contribution of both social and ecological factors as drivers of birth seasonality in a single model. We also use data from African Demographic Surveillance Sites and local weather stations.

1 Introduction

Seasonality of birth [1] is an essential but under studied feature of fertility patterns in developing countries. In much of sub-Saharan Africa (SSA), birth rates are seasonal and the

[1]Recurrent intra-annual fluctuations in births.

fluctuations in births are some of the strongest in modern times (Dorelien, 2011). Yet the cause(s) of the seasonal variation is not fully understood. There are large numbers of determinants that could influence the seasonality of births. Adding to the complexity, although birth is a single outcome, these determinants could exert their influence on any stage of the reproductive process beginning with sperm quantity/quality and regularity of ovulation to coital frequency to spontaneous abortion (Meade and Earickson, 2000). In this paper, we test to what extent four groups of hypotheses–social factors, climatological factors, energetic/labor force factors, and diseases are determinants of birth seasonality in sub-Saharan Africa. These hypotheses are not mutually exclusive and may exert their influence on birth seasonality concurrently. Consequently, whenever possible we use multivariate analysis to isolate the independent influence of different covariates. This paper is the first to include both sociodemographic and ecological variables in the same model when testing for potential drivers of birth seasonality. The findings in this paper will help us better understand the fertility transition in Sub-Saharan Africa (especially the role of social and environmental factors); and will give us important insight on how birth seasonality and overall fertility may respond to climate change.

In the remainder of this section, we present the background and mechanisms behind each set of potential drivers of birth seasonality.

Social and Cultural Factors

In developed countries, where individuals may not be closely tied to the environment, socio-demographic factors are assumed to be one of the leading causes of seasonal birth patterns (Ellison et al., 2005). Social factors may shape birth seasonality by influencing the frequency of intercourse. Religious and secular holidays have been associated with more or less coitus and thus conception. For instance in the United States, births peak in September possibly as a result of increased coitus during the Christmas-New Year holiday period; in France, conceptions peak during the August vacations resulting in May birth peaks. In Malaysia, different religious/ethnic groups have different patterns of birth seasonality reflecting the impact of Ramadan and Chinese New Year (Meade and Earickson, 2000; Rajan and James, 2000). Since religious holidays typically have a short duration of influence on likelihood of coitus and descriptive analysis of birth seasonality by religion did not reveal much within country variation across religions, therefore we hypothesize that religion will not be a major driver in SSA (Dorelien, 2011).

Another possible social determinant of birth seasonality is marriage time preference, which could produce "seasonal changes of the rate at which women enter (or leave) the population at risk" of conception Bobak and Gjonca (2001, page 1512). Given social pressure to give birth soon after marriage, seasonality in marriage time preference will have the highest influence on first parity timing. Seasonal fluctuations in marriage rates can be quite high, in the U.S. population the peak to trough difference is around 60 percent (Lam and Miron, 1991b). Ferguson (1987) found that the peak in births in September in Kenya corresponded with the peak in marriages in December. "December is the most popular month for marriages in Nairobi, 13.4 percent of all registered weddings in the years 1979-1983 took place during this month" (Ferguson, 1987, page 795) . However we must remember that cultural factors are not always divorced from agricultural factors. In their study of birth seasonality and marriage time preference in pastoral Italy during the 19^{th} century, Danubio et al. (2002) illustrate that marriage time preference is closely related to the agricultural cycle which includes male migration during the winter. It is also important to note that high levels of modern contraceptive use could reduce the influence of marriage seasonality on births.

Socio-demographic factors may also be correlated with birth seasonality by the intentional timing of pregnancy through the use of contraception. If some birth months are perceived to be advantageous, then more educated and wealthier women may be better able to accurately time their pregnancies through the use of birth control. Alternatively if birth seasonality is driven by climatological or energetic factors, and we assume that mothers living in urban areas and with higher levels of education/wealth may be more sheltered from these factors, then we would expect lower levels of birth seasonality in these women.

Climatological Factors

Climatological factors can influence both the frequency of intercourse and directly affect human fecundity (Ellison et al., 2005). Factors, such as rainfall and temperature, could influence when couples engage in intercourse. It's conceivable that during periods of rainfall, couples may spend more time indoors and therefore increase the likelihood of coitus. In the

Laikipia district in Kenya, the peak in conceptions (births minus nine months) coincided with peak in rainfall (Peralta, 2011). Still, seasonal climatic factors could also directly impact human reproductive capacity. Temperature and photoperiod (length of day from sunrise to sunset) are two drivers that fall under this heading.

The bio-mechanism behind the relationship between temperature and fertility is that high temperature negatively impacts sperm quantity and quality (Lam and Miron, 1996; Levine, 1994). Studies have shown that sperm production in mammals is temperature sensitive and optimized at temperatures below the core body temperature of many species (Ellison et al., 2005). Heat can suppress spermatogenesis in mammals. High temperature may raise female abdominal temperature, which may lead to irregular menstruation and ovulation, and failed implantation (Meade and Earickson, 2000; Bronson, 1995). Demographic evidence also seems to indicate that temperature may play a role in birth seasonality. Lam and Miron (1991a, 1996) found that in temperate zones with extreme summer heat such as the Southern United States, above normal summer temperatures were associated with below normal levels of conceptions. They repeated this analysis with data for many different countries (excluding African countries) and found similar results. However at higher latitudes and or locations with low summer temperatures other factors may play a leading role (Wehr, 2001). Recently, Manfredini (2009) found that in Italy from 1993 to 2005, both extremely high and low temperatures were associated with declines in conceptions. Unfortunately, the extent to which any of the above mechanisms is responsible for the relationship between temperature and birth seasonality is unknown.

According to the environmental light intensity/ photoperiod (ELI/PP) hypothesis, seasonal changes in light may also be driving birth seasonality (Cummings, 2010, 2002). This hypothesis is supported by the fact that in the pineal gland, melatonin production, which modulates reproductive cycle and circadian rhythm in many mammals has been found to be photosensitive in non-human mammals (Karsch et al 1984; Tamarkin et al. 1985; Bronson 1989). However, although melatonin secretion in human is photosensitive, it is unclear whether it mediates human reproductive cycle (in other words the downstream pathway connecting melatonin production and human reproduction may be broken) (Bronson, 1995; Ellison et al., 2005). Still "reproductive hormones have been shown to exhibit significant seasonal variation in men and women, with an increase in pituitary-gonadal function in late spring and early summer" (Wehr, 2001, page 354) (Levine, 1994). This evidence is further substantiated by seasonality of in vitro fertilization. According the the ELI/PP hypothesis increased ELI will precede peak of seasonal births (Cummings, 2010). Roenneberg and Aschoff (1990) found that at higher latitudes conceptions were correlated with day length.

Since our geographic area of interest is SSA, a large portion of our sample is located in the tropics where there isn't much seasonal variation in day length or temperature, therefore we will not test for the effect of photoperiod but instead for light intensity. And although we will test for the effect of temperature, we expect temperature to be a stronger driver in non-tropical locations.

Agricultural Cycle and Energetic Factors

The agricultural cycle can influence birth seasonality through a number of pathways. Seasonal variation in labor demand may result in household timing of births away from periods of peak labor demand (Nurge, 1970; Levy, 1986). This is tied to the economic theory of fertility, i.e. Becker (1960) which states that fertility decisions are linked to labor force participation and consumption. Here, the use of modern contraception would increase the likelihood of being born away from the period of peak labor demand. Seasonal agricultural migration could influence the times at which a women may become pregnant, with conceptions declining when husbands are away (Massey and Mullan , 1984).

Seasonal variation in nutrition and workload could explain the seasonal variation in births through its impact on energetic balance. In this case these hypotheses have an adaptive significance. "Food restriction can impair fertility in humans, causing, for example amenorrhea in women" (Wehr, 2001, page 355) (an illustrative example is secondary amenorrhea in anorexics). Therefore there could be a decline in conceptions during the hunger season. In north-east Zaire, Bailey et al. (1992) found that levels of conceptions were lowest among the subsistence Lese farmers when food availability was the lowest and ovarian function was reduced on the other hand the sympatric Efe pygmy foragers who did not experience strong fluctuations in food availability did not have significant fluctuations in conceptions. Excessive workload without compensatory increase in food can also inhibit fecundity.

Malaria, Fertility, and Fetal Loss

Disease can affect fertility in many ways. The increased incidence of disease has been linked to increase the rate of fetal loss (Lam et al., 1994). And in their model of birth seasonality, "increased fetal loss, combined with a delay in return to full susceptibility, provides one possible explanation for both the pronounced drop in conceptions in the hot summer months and the gradual increase in conceptions in the following months, with a peak several months later" (Lam et al., 1994). In this paper we analyze the impact of seasonal malaria incidence on birth seasonality. It has often been hinted in the scarce SSA literature on birth seasonality that malaria may influence birth seasonality. Leslie and Fry (1989) specifically mention that "malaria might contribute to seasonality of intrauterine mortality" . Bantje (1987) noted that in Tanzania "birth seasonality was found to be prominent only in areas, with holoendemic [2] malaria and is attributed to a seasonal depression of fecundity due to malaria infection"(page 733).

There is strong biological plausibility behind malaria's potential impact on birth seasonality. Pregnant women are more attractive to mosquitoes compared to non-pregnant individuals, and severe malaria is more common in pregnant women. Malaria is well known to cause of birth defects and low birth weights, but it in the earlier stages of pregnancy it is also associated with and increase risk in spontaneous abortions (Desai et al., 2007). Sharma (2009) reports that in India malaria in pregnancy caused and estimated 34.5 percent of abortions. The increased risk in fetal loss/abortions occurs because the high malarial induced fevers

[2] Holoendemic - year round transmission.

result in increased uterine activity and other damaging conditions for the fetus (McFalls and McFalls, 1984). To a lesser extent, anemia and placental parasitization are also associated with fetal loss. The pathology of malaria decreases with endemicity and gravidity (?). In malaria endemic areas, adult women have gained immunity after repeated exposure therefore avoid many of the symptoms of malaria, such as high fevers. Therefore we hypothesize that malaria will be a stronger driver in areas with epidemic/seasonal malaria and relatively low population immune levels compared to holoendemic areas. We also hypothesize that malaria incidence will have a stronger effect on first order births than with higher gravidity.

Historically there have been provocative results illustrating malaria's influence on human fertility. Fertility studies conducted after malaria elimination have documented an increase in fertility– contrary to the predictions of the demographic transition theory (?).

The current evidence suggests that social and cultural factors should be the strongest drivers of birth seasonality (Bronson, 1995). Of the ecological factors, the energetic challenge (food availability/work) should be the strongest driver. Below we see whether this research challenges these notions.

2 Data

Demographic and Health Surveys

The data used to test for social and cultural drivers of birth seasonality comes from the Demographic and Health Surveys (DHS). The DHS are nationally representative surveys of women of childbearing age (15-49 years old) carried out in developing countries. The DHS is ideally suited for this because in addition to containing complete reproductive histories with date of birth[3] of each child the women have ever had, we also have a wealth of demographic covariates. For instance we have information on whether the mother is in a union/marital status, contraceptive use, the month and year of first union/marriage, her educational background, type of place or residence (rural or urban), religion, age (from which we can calculate her age at child's birth), and child's birth order and sex.

The Demographic and Health Surveys have been previously used to document birth seasonality in SSA (Dorelien, 2011). Although the DHS allows us to calculate birth seasonality of a wide range of countries, some countries are better suited than others because of sample size and data quality issues (Dorelien, 2011). Therefore we limit this analysis to the following ten countries with large sample sizes and/or strong seasonal birth patterns–Nigeria, Mali, Tanzania, Madagascar, Kenya, Malawi, Zambia, Uganda, Congo DR, and Sierra Leone (table 1).

Demographic Surveillance Sites

We also use data from Demographic Surveillance Sites (DSS). DSS were chosen because they contain both demographic and disease data and represent a relatively small geographic area. Given the small geographic area, we are also able to obtain time series of climatological data from nearby weather stations. We currently have data from the following DSS locations-Kilifi (Kenya), Magu (Tanzania), and Agincourt (South Africa).

[3] In some instances either the birth month or year are missing and imputed from auxiliary information. In this analysis we drop all imputed observations.