Record high fertility in sub-Saharan Africa in a comparative perspective

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Abstract

The study documents cases of extremely high fertility in sub-Saharan Africa. The DHS surveys were used for the analysis, with straightforward calculations of period and cohort fertility. Two case studies were further analysed: Kenya (1965-69) and Niger (1982-86). In both cases, total fertility in rural areas reached 9 children per woman, as high as among the Hutterites of North-America (1921-1940). However, the complete family size never exceeded 8.0 children per woman in Kenya (cohorts 1939-1946) and 8.2 children per woman in Niger (cohorts 1960-1967). Compared with the Hutterites, in both African countries the age pattern of fertility was earlier and with a lower mode, age at marriage was earlier, birth intervals were longer because of long breastfeeding, and secondary infertility was more frequent after the 5th birth. Other proximate determinants of fertility appeared similar in the three populations, with the probable exception of health and nutritional status. Implications for modelling are discussed.

Key words: Natural fertility; Maximum fertility; Proximate determinants; Nuptiality; Primary infertility; Secondary infertility; Breastfeeding; Kenya; Niger; Hutterites; sub-Saharan Africa.

Introduction

The concept of natural fertility was introduced in 1961 by Louis Henry to characterize the situation of populations who were not limiting their family size, in contrast to others who were using various means of birth control in order to limit the number of children ever-born to their desired number. [Henry, 1961a, b]. Natural fertility covers a wide variety of situations, with average levels per woman ranging from 4 children or less to 8 children or more. Variations in natural fertility are due to a wide array of factors: biological factors, that is the various parameters of reproductive health (primary and secondary infertility, nutrition, diseases, etc.), as well as behavioral factors, such as marriage (age at marriage, proportion ever-marrying), sexual taboos (premarital taboo, post-partum abstinence), coital frequency, separation of spouses, etc. A wide body of literature covers these issues. [Diggory et al., 1988; Garenne & Frisch, 1994; Leridon, 1977; Leridon & Menken, 1979; van de Walle, 1988].

The common framework for studying variations in fertility in general, and natural fertility in particular, is the so-called "proximate determinants" framework. This framework classifies the main factors influencing human fertility, including contraception and induced abortion. This framework was introduced in 1956 by Kingsley Davis and Judith Blake, and has been further refined by numerous authors, in particular John Bongaarts. [Davis & Blake, 1956; Bongaarts, 1976, 1978, 1980; Bongaarts & Potter, 1983] Among biological factors, two factors may strongly affect natural fertility: nutrition and diseases. The effect of nutrition on menarche and fecundity has been extensively studied. [Chowdhury,1978; Frisch, 1975, 1978, 1984, 1990; Frisch & Revelle, 1971; Frisch et al., 1980; Menken et al., 1981; Wyshak & Frisch, 1982]. The effect of sexually transmitted diseases, of tuberculosis, and of some tropical parasitic diseases (e.g. malaria, trypanosomiasis, schistosomiasis, etc.) is also well documented, with major implications for Tropical Africa. [McFalls & McFalls, 1984; Retel-Laurentin, 1978]. Since these earlier studies, HIV/AIDS emerged, with also an impact on infertility. Among behavioral factors, besides nuptiality, two factors are of particular relevance for sub-Saharan Africa: breastfeeding and post-partum abstinence. [Page & Lesthaeghe, 1981].

Natural fertility has been well documented in historical populations of Europe (France, Switzerland, England, Germany, Sweden, etc.) and overseas European populations, in particular in North America. The world record of outstandingly high fertility is owned by the Hutterites, an Anabaptist sect living in Northern Dakota. This group originated from Moravia, who migrated to Russia and later to North America in the second part of the 19th century [Eaton & Mayer, 1953]. This is a small size rural population, well nourished, with universal marriage, short breastfeeding, short birth intervals, and record high fertility (9 children per woman). This population is used in demography as a reference set for modeling natural fertility and for assessing the extent of controlled fertility. [Coale and Trussell, 1974]. Another population with extremely high fertility is the Quebec population of the 19th century, with almost as high total fertility. [Charbonneau, 1979; Eijkemans et al., 2014; Henripin 1954].

If European populations are well studied, much less research has been done on African populations. Currently, African countries have the highest fertility in the world, declining slowly over the past 30 years. This period of fertility decline occurred after a period of rising fertility, associated with improving health and nutritional status, going back probably to the early days of colonization at the beginning of the 20th century. [Romaniuk 1980]. Most important in sub-Saharan Africa was the quasi-disappearance of large pockets of primary infertility following diseases control programs (preventive and curative) and the introduction of modern medicines (antibiotics, antimalarial drugs in particular). A literature search on natural fertility in Africa leads only a few titles. [Cantrelle & Leridon, 1971; Khalifa, 1986; Regassa, 2006; Thibon, 1988]. Furthermore, the period of peak fertility has been little studied, not counting the fact that it varies from country to country and between urban and rural areas. [see Garenne, 2008 for details].

The aim of this paper was to document two cases of record high fertility (TFR ≥ 9) in sub-Saharan Africa, to compare them with the Hutterite reference, and to analyze as much as possible their patterns and the proximate determinants associated with these very high values. The ambition is not to give a complete study of fertility in Africa, but simply an analysis of two African records, which can also be considered among the world records of high fertility.

Data and methods

Data were derived from Demographic and Health Surveys (DHS), the main source of information on fertility trends, patterns and proximate determinants in Africa. In some cases, data were taken from published sources (DHS final reports) or from the Stat-Compiler module of the DHS program web site, and in other cases tabulations were produced from the individual datasets. Period fertility was estimated by computing age-specific fertility rates by 5-year age group and yearly periods, then cumulated as needed for longer periods (e.g. 5-year). For studying trends, fertility rates were cumulated to age 40, then extrapolated for computing TFR. This was necessary because of the nature of retrospective surveys conducted among women age 15-49: they cover the age group 12-44 in the 5 preceding years, and the age group 12-39 in the 10 preceding years. So cumulating fertility up to age 40 was the choice method to estimate levels and trends over time. Cohort fertility was computed directly from children ever-born, also cumulated to age 40 for studying trends for the same reason of age truncation. The main reason for calculating both cohort and period fertility was that the peak of period fertility, the most often quoted in the literature, was transient, and differed from the highest values recorded among cohorts. The period of peak fertility was selected as 5 years around the peak year, that is from 2 years before to 2 years after. Details of the computational procedures were presented elsewhere. [Garenne, 2008].

A number of proximate determinants were considered. In most instances, estimates were taken from DHS reports, for the year as close as possible from the reference period. Whenever possible, indicators were recomputed from the DHS datasets for the exact period of peak fertility. Premarital fertility (the proportion of births that occurred before first marriage) was obtained by straightforward tabulation, as was the mean age at last birth. Median age at puberty and at menopause were obtained by linear-logistic regression on the corresponding proportions of women age 15-20 in the first case, and age 40-49 in the second case. This procedure provides a precise estimation of median age at puberty and menopause. Comparative data pertaining to the Hutterites were taken from the original publication. [Eaton & Meyer, 1953] This document contains however little information on proximate determinants. They were sometimes supplemented with data from other North American populations (USA or Canada).

Results

Overview

Fertility levels vary considerably in rural areas of sub-Saharan Africa. In published statistics from DHS surveys, the TFR ranges from 3.9 (South Africa, 1998) to 8.1 (Niger 2012), with a mean of 6.2 children per woman. Several countries appear as having very high fertility, defined by TFR≥ 7.0 in rural areas: in East-Africa: Uganda (7.6), Zambia (7.5), Kenya (7.1), Burundi (7.0); in Sahelian West-Africa: Niger (8.1), Mali (7.4), Senegal (7.1), Burkina Faso (7.0); in Coastal West-Africa: Liberia (7.5), Togo (7.3), Ghana (7.0), in Central Africa: Angola (7.8), Congo (7.0). These data are based on fertility rates in the 3-year period before the surveys, conducted at various times between 1985 and 2014, and therefore cover selected periods, differently for each country, depending on the time at which the survey was taken. [Source: DHS web site, StatCompiler, accessed September 30, 2014].

Peak period fertility

A more precise estimation of peak fertility levels was obtained by reconstructing cumulated fertility by age 40, denoted here: TFR(40). In brief, age-specific fertility rates are computed for each of the 10 years before the survey from age 12 to 39, and cumulated to age 40, which gives a deeper insight into past fertility trends. [Garenne, 2008]. According to this reconstruction, peak fertility (TFR(40) ≥ 7.0) occurred in about the same list of countries, but often at earlier periods than those covered by the 3 years before DHS surveys. In East-Africa, four countries stood out: Kenya, Zambia, Uganda, and Rwanda. In Kenya, peak fertility in rural areas occurred in 1965-69, in Zambia in 1974-78, in Rwanda in 1980-84, in Uganda in 1970-74. In Sahelian West-Africa, four countries stood out: Niger (1975-79), Mali (1987-1991), Burkina Faso (1977-1981), and Senegal (1979-83). In Coastal West-Africa, three countries stood out: Togo (1976-80), Cote d'Ivoire (1978-82), and Benin (1986-90). In most of those countries fertility underwent a serious decline after the period of peak fertility. However, rural fertility stayed at high levels in Niger, Uganda, and Zambia (see Table 1).

Table 1: Situations of peak period fertility in African DHS surveys (rural areas)

Region	Country	Period of peak fertility	Cumulated fertility by age 40
East Africa			
	Kenya	1965 - 1969	7.93
	Zambia	1974 - 1978	7.30
	Rwanda	1980 - 1984	7.23
	Uganda	1970 - 1974	7.13
West Africa, Sahel		-	
	Niger	1982 - 1986	8.28
	Mali	1987 - 1991	7.92
	Burkina Faso	1977 - 1981	7.56
	Senegal	1979 - 1983	7.27
West Africa, Guinea gulf			
	Togo	1976 - 1980	7.32

Cote d'Ivoire	1978	-	1982	7.26
Benin	1986	-	1990	7.19

NB: Countries with cumulated period fertility by age 40 > 7.0 over a 5-year period. Source: reconstruction from DHS surveys.

Two countries stood out with exceptionally high period fertility: Kenya and Niger, which were selected for the in-depth analysis. In Kenya, rural fertility, measured by TFR(40), increased in the 1950's, peaked in 1965-69, stayed close to the maximum level until 1982, before declining to reach 4.3 in 2010. So, the situation of rural Kenya in the late 1970's (at time of the 1978 WFS survey) was close to that during the peak of fertility. In Niger, rural fertility increased markedly in the 1950's and 1960's, peaked in 1982-86, declined somewhat, then increased again to peak again around 2006, before resuming its decline. So, in this case also, the situation at time of the 1992 DHS survey appears as similar to that prevailing at time of the peak fertility.

Age patterns of peak period fertility

For the three situations of outstandingly high fertility (Kenya, Niger and the Hutterites), the levels of cumulated fertility at age 50 appeared as equivalent (TFR= 9.28, 9.16, and 9.07 respectively). Note that due to limited sample size, these differences were not statistically significant: the 95% confidence intervals were: 8.98-9.57 in Kenya, 8.88-9.44 in Niger, and 8.60-9.53 for the Hutterites.

The age patterns of fertility during the period of peak fertility differed between the three populations. Compared with the Hutterites, the two African populations had an earlier fertility (mean age at birth: 30.1 years in Kenya, 28.8 years in Niger vs 32.3 years for the Hutterites), a lower and earlier peak (367 per 1000 at age 20-24 years in Kenya, 373 per 1000 at age 20-24 years in Niger vs 445 per 1000 at age 25-59 years for the Hutterites), and an earlier decline of fertility rates with age. As will be seen with more details later, these differences were due to earlier marriage in Africa compensated by longer birth intervals and higher secondary infertility. Values of age-specific fertility rates in the last age group (45-49) were questionable: they appeared higher in the two African populations. This might be real, but could also be due to age over-statement in Kenya and Niger, since the age trend should reach 0 around age 50. In terms of cumulated fertility, the three populations reached the same level, with an earlier start but a smaller slope for Niger and the opposite for the Hutterites, Kenya being close to Niger. (see Figure 1, Table 2)

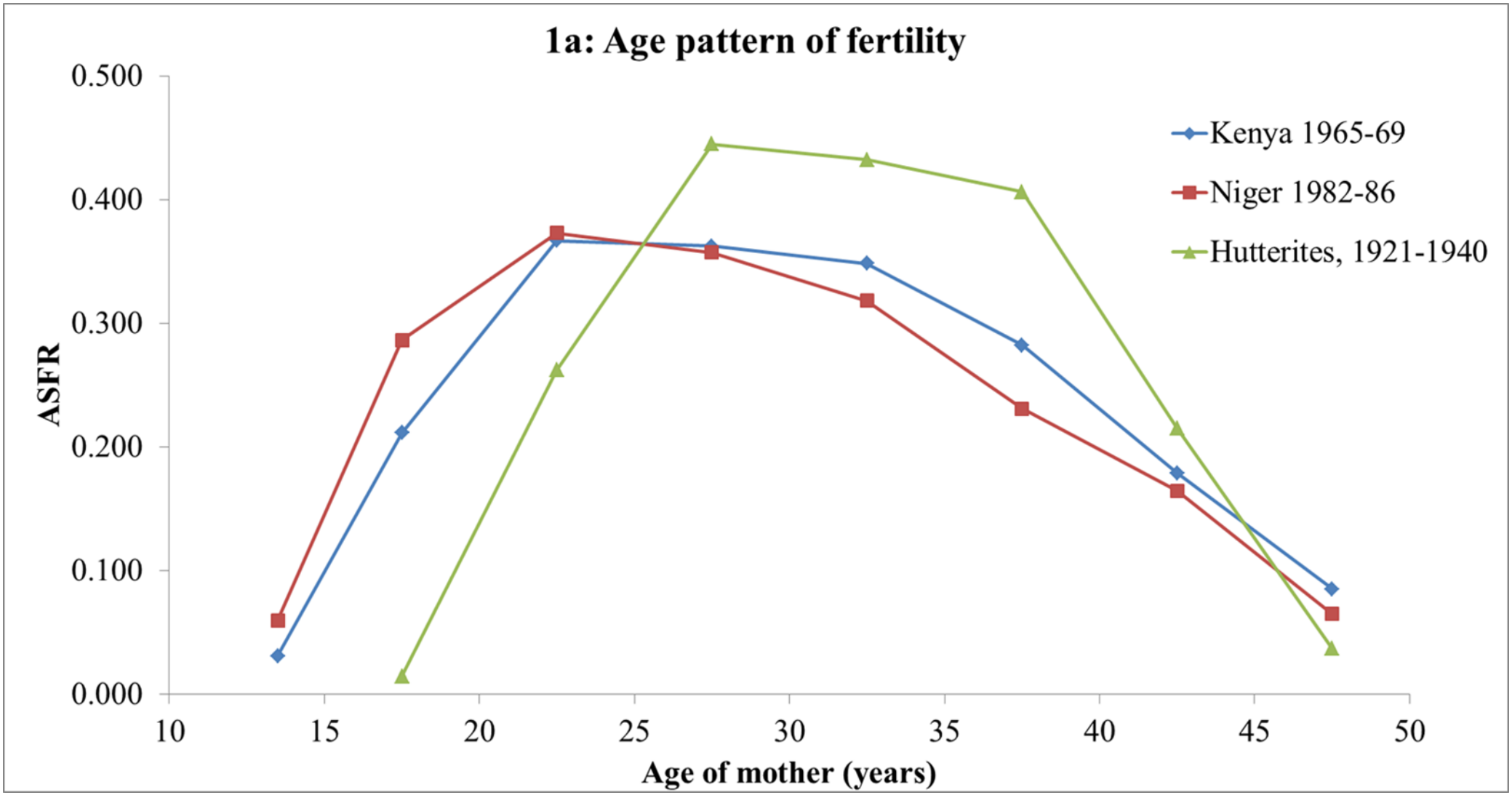
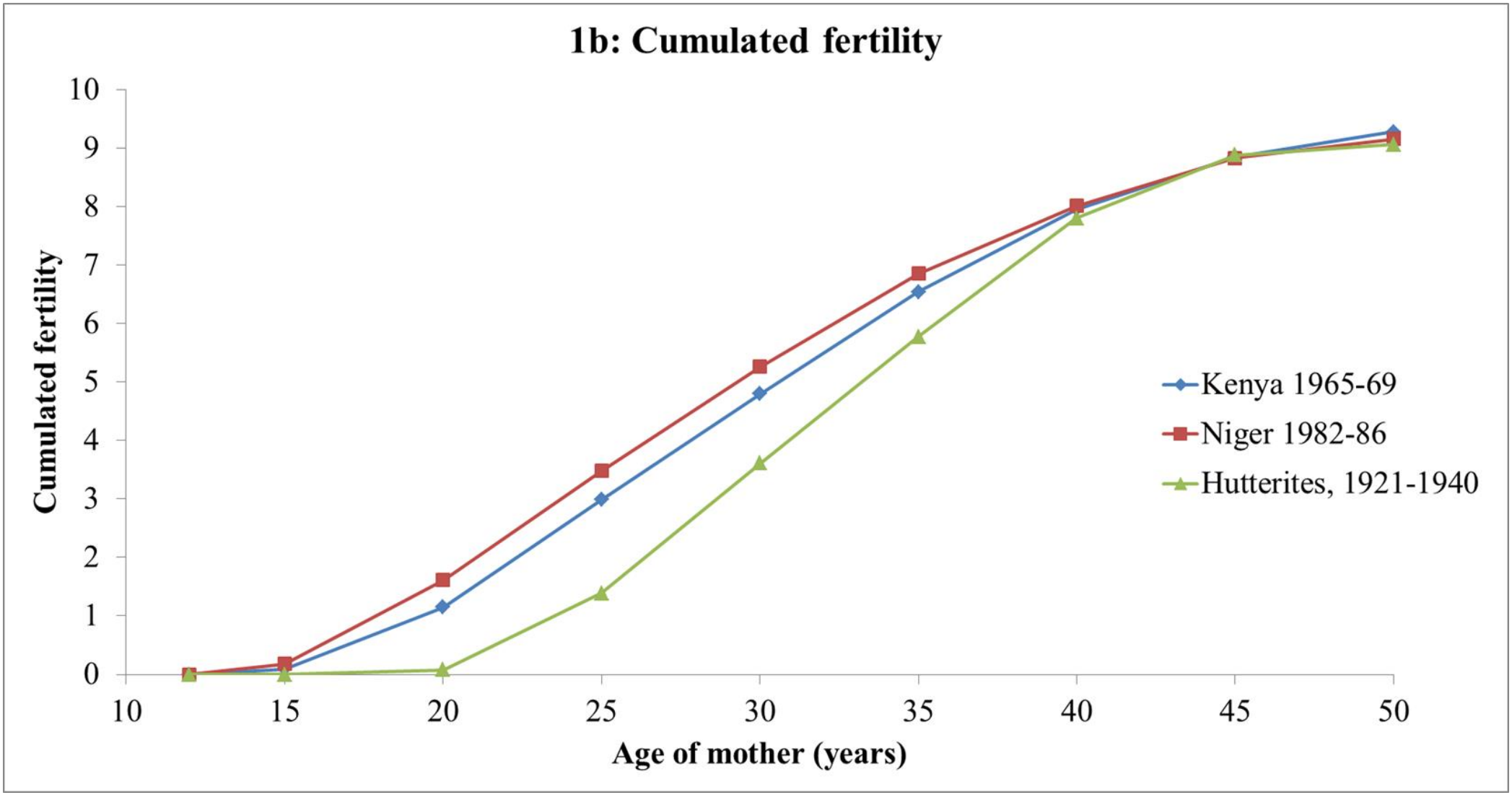

1a: Age pattern of fertility
0.500
0.400
0.300
0.200
0.100
0.000
ASFR
10
15
20
25
30
35
40
45
50
Age of mother (years)
Kenya 1965-69
Niger 1982-86
Hutterites, 1921-1940

Table 2: Fertility rates and cumulated fertility, 3 situations of outstanding fertility

		Population (rural) and Period		
	Age group /	Kenya	Niger	Hutterites
	Age limit	1965-1969	1982-1986	1921-1940
Age-specific fertility rates (/1000)				
	12-14	31	60	0
	15-19	211	287	15
	20-24	367	373	262
	25-29	363	357	445
	30-34	349	318	432
	35-39	283	231	406
	40-44	179	165	215
	45-49	85	65	37
Cumulated period fertility				
	15	0.09	0.18	0.00
	20	1.15	1.61	0.07
	25	2.99	3.48	1.38
	30	4.80	5.27	3.61
	35	6.54	6.86	5.77
	40	7.96	8.01	7.80
	45	8.85	8.83	8.88
TFR	50	9.28	9.16	9.07


1b: Cumulated fertility
Cumulated fertility
0
1
2
3
4
5
6
7
8
9
10
10
15
20
25
30
35
40
45
50
Age of mother (years)
Kenya 1965-69
Niger 1982-86
Hutterites, 1921-1940

Peak cohort fertility

Since fertility underwent major changes in Africa, it was important to compare period fertility with cohort fertility, that is the complete family size (CFS). Here again, in order to compare cohorts, the number of children born by age 40 was computed, labeled CEB(40). In DHS datasets, peak cohort fertility (CEB(40) ≥ 7.0) occurred basically in the same countries, with the addition of Chad and Cote d'Ivoire, for cohorts of women born in the 1940's and 1950's, somewhat later in Niger and Chad. Here again Kenya and Niger appeared as outstanding, one more justification for their selection for the in-depth case study. A cumulated number of children of 7.5 at age 40 corresponds to a CFS of 8.3 at age 50, which is below the world record of the Hutterites (CFS = 9.0 for cohorts born in 1865-1904). In fact no African country reached the level of cohort fertility achieved by the Hutterites with a statistically significant test. (See Table 3).

Table 3: Situations of peak cohort fertility in African DHS surveys (rural areas)

Region	Country	Cohorts of peak fertility	Cumulated fertility by age 40
East Africa			
	Zambia	1944 - 1948	7.56
	Kenya	1944 - 1948	7.45
	Rwanda	1946 - 1950	7.39
	Uganda	1940 - 1944	7.38
West Africa, Sahel			
	Niger	1965 - 1969	7.75
	Mali	1953 - 1957	7.46
	Chad	1960 - 1964	7.19
	Senegal	1954 - 1958	7.13
	Burkina Faso	1950 - 1954	7.09
West Africa, Guinea gulf			
	Togo	1942 - 1946	7.12
	Benin	1952 - 1956	7.01

NB: Countries with cumulated cohort fertility by age 40 ≥ 7.0 over 5-years of cohorts. Source: reconstruction from DHS survey.

Three case studies of record fertility

The remainder of this paper deals with Kenya and Niger, in comparison with the Hutterites. Periods of peak fertility were 1965-69 for Kenya, 1982-86 for Niger, and 1921-41 for the Hutterites. The period TFR was the same in the three cases, with similar number of births and confidence intervals. Cohorts of peak fertility were 1939-46 for Kenya, 1960-67 for Niger and 1865-1904 for the Hutterites. The cohorts do not precisely match the periods of peak fertility, but are close for both African countries. For the Hutterites, many of the women in the selected cohorts had births before 1921, which matters little because fertility appeared very steady in this

population: TFR and CFS do match, which was not the case in Africa, where period TFR underwent ups and downs and exceeded corresponding CFS. Cohort fertility was significantly higher among the Hutterites compared with both African countries. ($P < 0.001$ in both cases). (See Table 4, Figure 2a)

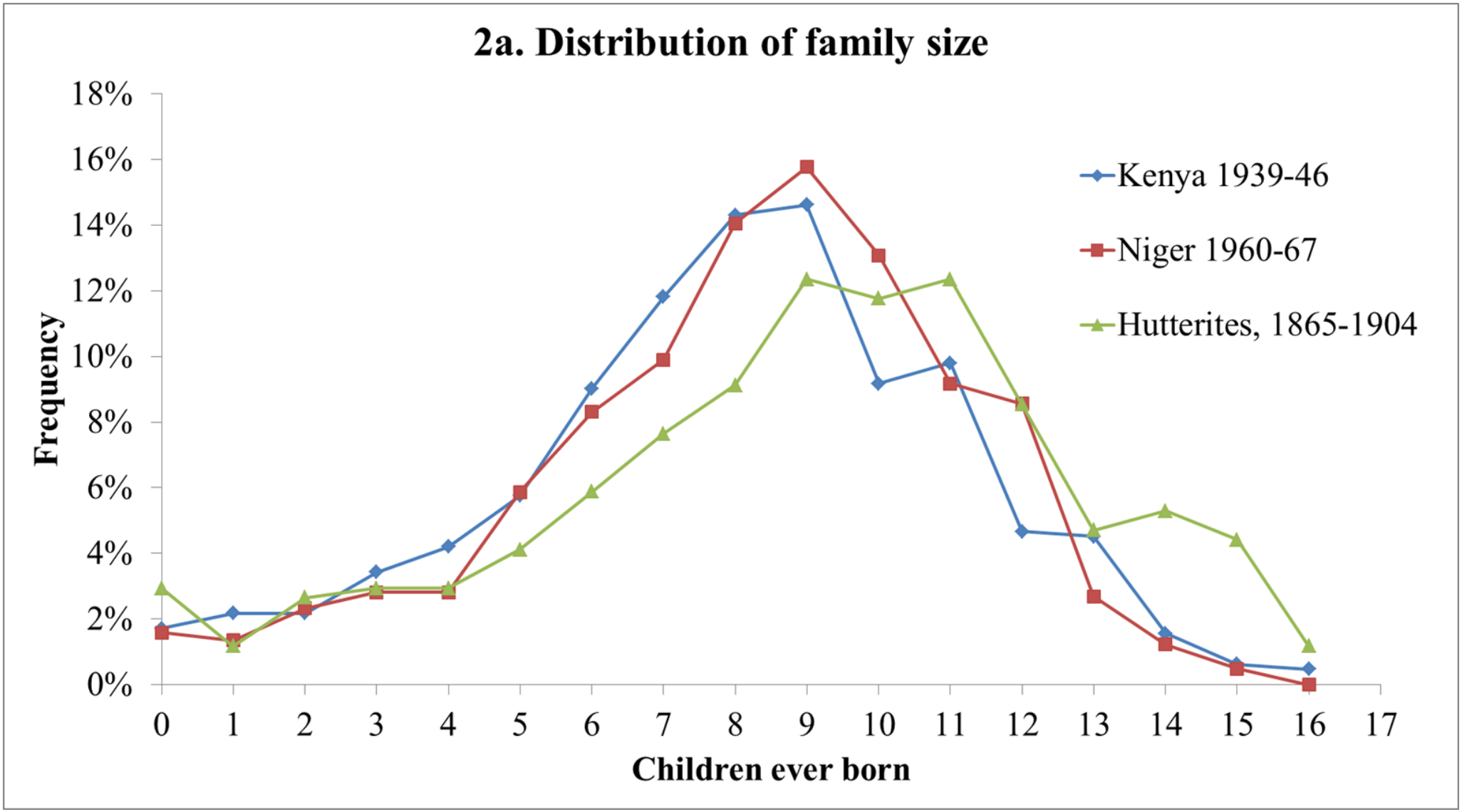
Table 4: Selected cases studies of record fertility

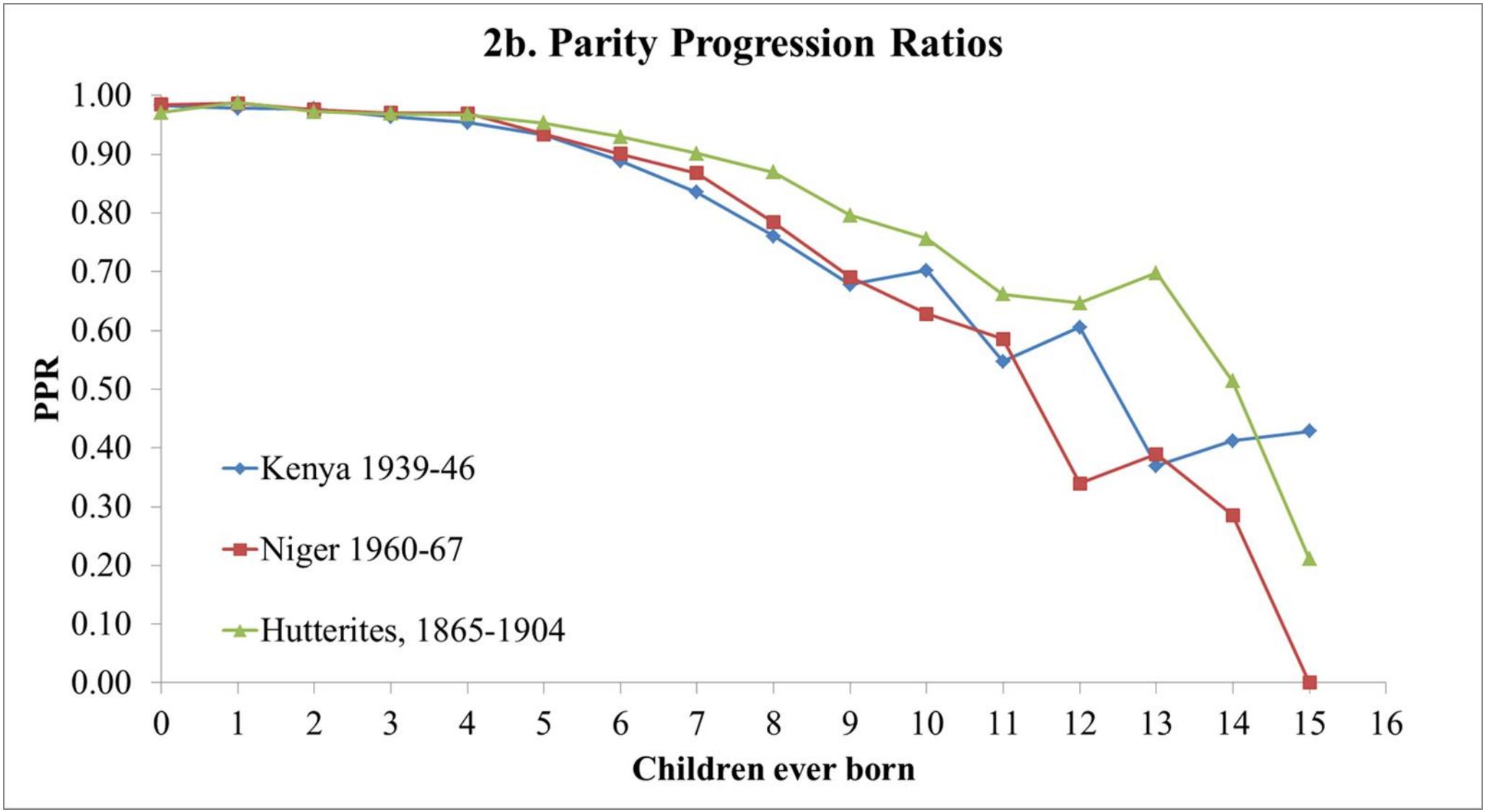
		Kenya	Niger	Hutterites
Period fertility				
	Period	1965-1969	1982-1986	1921-1940
	Nb of births	6317	5913	4869
	Total fertility rate	9.28	9.16	9.07
	Confidence interval	±0.30	±0.28	±0.27
Cohort fertility				
	Cohorts	1939-46	1960-67	1865-1904
	Nb of women	643	818	340
	Complete family size	7.98	8.22	8.97
	Confidence interval	±0.24	±0.20	±0.39

NB: Width of confidence interval is calculated as 1.96 times the standard error.

Parity progression ratios at peak cohort fertility

The distribution of children ever-born for cohorts with peak fertility allowed one to compute parity progression ratios. In all three populations the maximum number of births per woman was 16 children ever-born. Compared with the Hutterites, the two African populations had a lower modal value (9 children), and more women with 5-9 children (55.5% in Kenya, 53.9% in Niger, vs 29.7% among the Hutterites), and less women with 10 children or more (30.8% in Kenya, 35.2% in Niger, vs 48.2% among the Hutterites). This indicates higher frequency of secondary infertility among both African populations. (See Figure 2b).


2a. Distribution of family size
Frequency
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Children ever born
Kenya 1939-46
Niger 1960-67
Hutterites, 1865-1904


2b. Parity Progression Ratios
PPR
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Kenya 1939-46
Niger 1960-67
Hutterites, 1865-1904
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Children ever born

Another way of looking at infertility is to compare parity progression ratios. The two African populations appeared again similar, with only minor differences, not statistically significant. Primary infertility was the same in the three populations: 1.7% in Kenya, 1.6% in Niger, vs 2.9% among the Hutterites, none of the difference being significant. Secondary infertility from 1 to 5 children (the probability of having less than five children if already had one) was also the same, with no significant difference (12.2% in Kenya, 9.4% in Niger, vs 10.0% among the Hutterites). However, secondary infertility from 5 to 10 (the probability of having less than ten children if already had five) was significantly higher in the two African populations: 64.3% in Kenya, 60.5% in Niger, vs 44.8% among the Hutterites ($P< 10^{-8}$ and $P< 10^{-6}$ respectively). Parity progression ratios were similar in the three populations up to birth order 5, but significantly lower thereafter in both African populations compared with the Hutterites. This shows that acquisition of secondary infertility occurred earlier in Africa, the mean age at the 5th birth being about 27 years in Kenya and Niger.

Proximate determinants

This section compares proximate determinants in the three situations. Of course, precise data at time of the peak fertility were not always available, and proxies were used instead. Available data are shown in Table 5.

Table 5: Selected proximate determinants of fertility, three case studies of record high fertility

	Proximate determinant	Kenya	Niger	Hutterites
Nuptiality	Terminal celibacy	0.3%	0.1%	1.7%
	Widowed, divorced	8.3%	3.6%	Low
	Median age at marriage	18.4	14.9	21.2
	Polygyny	31.9%	36.4%	None
	Premarital births	20.2%	2.8%	Low
Behavior	Contraceptive use	7.8%	0.4%	None
	Frequency of intercourse	53.8%	67.0%	?
Susceptibility	Primary infertility	1.7%	1.6%	2.9%
	Secondary infertility 1-5	12.2%	9.4%	10.0%
	Secondary infertility 5-10	64.3%	60.5%	44.8%
	Puberty (years)	15.0	15.5	~15
	Menopause (years)	49.9	50.1	~50
	First birth (years)	18.9	17.8	~22
	Last birth (years)	39.8	39.3	~40
Birth intervals	Mean length (months)	31.4	30.3	23.2

	Breastfeeding (months)	20.9	21.0	< 12
	Post-partum amenorrhea	11.6	16.4	Short
	Post-partum abstinence	3.2	2.2	Short
	Infant mortality (/1000)	62	208	39
Anthropometry	Height (cm)	159	160	~160
	BMI (kg/m^2)	21.7	20.3	~24

Source: DHS reports, and calculations from DHS datasets, rural areas only. Average from the two earlier DHS surveys (e.g. Kenya 1988, 1993; Niger 1992, 1998). For terminal celibacy and proportion out of union, Kenya 1978 WFS. Age at puberty and menopause obtained by linear-logistic regression. Mean age at last birth calculated for cohorts 1927-1939 in Kenya, and 1960-1967 in Niger. For the Hutterites, some of the estimates (marked with ~) were derived from other North American populations with similar characteristics.

Nuptiality

Terminal celibacy, defined as being never-married at age 40-49 was rare in all three cases: 1.6% in Kenya (1988 and 1993 DHS surveys), 0.1% in Niger (1992 and 1998 DHS surveys), and 1.7% among the Hutterites (1926-1940). Median age at first marriage was different in the three situations, spaced by some 3 years each: very early in Niger (14.9 years), medium for Africa in Kenya (18.2 years), and typical of European populations of that time among the Hutterites (21.2 years). Note that a 3-year difference in age at marriage implies about one additional birth, and explains the gap of 2 children at age 20 between Niger and the Hutterites. (See Figure 1b).

Premarital fertility

The gap in age at first marriage between Niger and Kenya translated into a minor difference in children ever-born by age 20 because premarital fertility (defined as birth before first marriage) was prevalent in Kenya, whereas it hardly existed in Niger, where first marriage follows shortly puberty, and first intercourse occurs at time of first marriage. In Kenya, some 20.2% of births to mothers aged less than 20 in the 1960's and 1970's were premarital, whereas the corresponding proportion for Niger was 2.8% only. [Garenne & Zwang, 2006]. Universal and early marriage was possible in Niger in part because of the high prevalence of polygyny (36.4%), higher than in Kenya. The proportion of women widowed, divorced or separated was small in Niger (3.6%), but somewhat higher in Kenya (8.3%) with some possible negative effect on fertility.

Contraception

Contraceptive use was probably non-existent among Hutterites women living before 1940, very rare in rural Niger in the 1980's and rare in rural Kenya in the 1960's. Contraceptive prevalence available in the four DHS surveys of Niger and the five DHS surveys in Kenya predicted by linear-logistic regression a contraceptive prevalence of 0.4% in Niger and 7.8% in Kenya (possibly overestimated by the model), which is unlikely to have had any major impact. There is no data on induced abortion in any of the three populations, and it is expected to be rare. Frequency of intercourse appeared average in Kenya (53.8% of women having intercourse in the past 4 weeks), somewhat lower than in Niger (67.0%), a small difference probably without much impact on fertility. The proportion of women aged 30-49 years who had no sexual intercourse in the past 3 years (due to sexual taboo or to spouse separation) was also small in the two African countries: 6.5% in Kenya, 4.0% in Niger, somewhat below the African average in DHS surveys (6.7%). No corresponding figure is available for the Hutterites.

Primary and secondary infertility

As mentioned above, primary infertility was low and similar in the three populations (range 1.6% to 2.9%), as secondary infertility from birth order 1 to 5 (range 9.4% to 12.2%). Secondary infertility for higher birth orders (> 5) differed significantly, with higher values for both African populations, and probably for biological reasons (see Figure 2b). Median age at puberty seemed stable in Kenya and Niger around 15 years, which is close to that of North Americans at the turn of the 20th century. [Wyshak & Frisch, 1982] In the case of the Hutterites, age at puberty mattered little since marriage occurred much later and there was virtually no premarital fertility. Age at menopause seemed also stable in Kenya and Niger, around 50 years, again

similar to that of North Americans in the early years of the 20th century. [Garenne & Frisch, 1994]. Age at first birth followed the age at marriage in both African populations. In Kenya, age at last birth was stable for cohorts born before 1940 (39.8 years), then tended to decline reflecting the onset of family planning. In Niger, age at last birth was increasing, probably because declining secondary infertility, and reached 39.3 years for cohorts born in the 1960's. So, at time of peak fertility both African populations seemed comparable to North American populations in terms of the exposure period from puberty to menopause.

Birth intervals

Birth intervals were long in both African populations: 31.4 months in Kenya and 30.3 months in Niger, typical of most African populations where duration of breastfeeding is extended (20.9 months in Kenya, 21.0 months in Niger). In both Kenya and Niger post-partum abstinence was short (3.2 months and 2.2 months respectively). Durations of post-partum amenorrhea and of the non-susceptible period were long, mainly because of long breastfeeding. Birth intervals were much shorter among the Hutterites: 23.2 months. [Sheps, 1965] This is probably due to a very different pattern of breastfeeding, well documented among the Hutterites: short duration of exclusive breastfeeding, quick introduction of supplements, as early as 6 weeks or less, breastfeeding at fixed time during the day and for short periods of time (< 10 minutes), use of pacifier to calm the baby, and early weaning (< 12 months), whereas in Africa the breastfeeding period is long (about 2 years), exclusive for several months (5-6 months), on demand, and with long sucking periods of time, and no pacifier is ever used. [Huntington and Hostetler, 1966]. This African pattern of breastfeeding has a considerable impact on the duration of post-partum amenorrhea, and therefore on birth intervals, when compared with that of the Hutterites. [Sheps, 1965].

Health and nutrition

Health was obviously different in African countries, in comparison with North-American populations, as shown by differences in child mortality. Kenyan and Nigerian women were relatively tall (160 cm), as most adults belonging to Sahelian groups, and as tall as North American women. However, their BMI was relatively low: 21.7 and 20.3 kg/m^2 respectively, probably lower than that of North-American women living at the beginning of the 20th century. The NHANES survey conducted in 1960 in the USA gives a mean height of 160 cm and a BMI of 23.9 kg/m^2 for women age 20-49. Given that women were about the same mean height in the three populations, the BMI and therefore the weights appear about 10% lower in Kenya and 20% lower in Niger, which is considerable and indicates large differences in body composition. This might account, at least in part, for lower fecundity, longer post-partum amenorrhea associated with long breastfeeding, and possibly more frequent secondary infertility. In terms of diseases, North American women at that time were probably free of any serious disease causing infertility. The periods during which both African populations were studied were free of HIV/AIDS, a serious cause of infertility at the end of the 20th century. Malaria, a disease which may cause spontaneous abortion, is highly prevalent and severe in Niger, less so in Kenya, Obviously, malaria had no major demographic impact, since Niger had record high fertility, as was the case of other Sahelian countries such as Mali, Burkina-Faso and Senegal, also affected by severe malaria.

Possible behavioral factor of secondary infertility

An alternative hypothesis to higher frequency of secondary infertility among African population could be spouse separation or sexual taboo. In particular, in some African societies women are assumed to no longer have sexual intercourse when they have a married daughter who has children. In addition, in societies with high prevalence of polygyny, competition between spouses might be in favor of younger recently married wives. This however did not seem to be the case in Kenya and Niger. Firstly, the proportion of women who have not had sexual intercourse in the past 3 years increased with age above age 40 (as expected), but remained relatively small : in Kenya: 1.8% at age 30, 6.1% at age 40 and 21.5% at age 49; in Niger: 2.0% at age 30, 3.5% at age 40 and 8.2% at age 49. Secondly, cumulated fertility of women who had not had sexual intercourse in the past 3 years was rising with age from 30 to 49, as was the case for women who had sexual intercourse, although at a somewhat lower average level (5.68 versus 5.22 children ever born). This indicates that cases of long abstinence were transient, possibly due to the temporary absence of the husband, and did not have much impact on secondary infertility. Thirdly, the hypothesis of an impact of being a grand-mother was tested by comparing the cumulated fertility of women age 30-49 of those who had a girl age 20 and above, with that of women who did not. Results showed only a minor impact, not statistically significant. In multivariate analysis, after controlling for age and cohort trend, the probability of not having sex in the past 3 years was basically the same for potential grand-mothers and for others: in Kenya 5.6% (if

daughter age 20+) versus 4.9% (if not), P= 0.100; in Niger: 3.3% (if daughter age 20+) versus 3.4% (if not), P= 0.597. In summary, the sexual taboo associated with having a daughter with children did not seem to apply to these two African cases.

Discussion

This study presented two cases of record high period fertility, in Kenya and Niger, where rural populations had a total fertility (TFR) equivalent to that of the Hutterites living in North America in the first part of the 20th century, considered as the maximum of human fertility. However, the paths followed by these populations to reach 9 children per women were different. The African populations achieved high levels of fertility by very early marriage, compensated somewhat by premarital fertility in Kenya, despite long birth intervals associated with long breastfeeding, and despite higher secondary infertility associated with lower health and nutritional status. The Hutterite population chose later marriage and shorter birth intervals, made possible by better health and nutritional status, and a different pattern of breastfeeding.

In terms of cohort fertility, the two African populations did not reach the level achieved by the Hutterites (also 9.0 children per woman at age 50). This indicates that the record high period fertility in Africa was transient, and in part due to a short term tempo effect. Earlier and later periods had lower fertility, and the periods during which fertility was at its maximum were relatively short, compared with the Hutterites where it lasted probably at least half a century. According to available data, no African population seems to have ever exceeded 8.5 children ever-born per woman for an extended period of time (cohort fertility).

There is no reason to question the quality of DHS surveys data. There are some minor well documented biases in such surveys (displacement of some births occurring 5 years before, inclusion of some perinatal deaths, selection for more fertile women), but the main limitation is really sample size and sampling scheme. [Schoumaker 2014] Here we selected samples large enough to have reasonable confidence intervals, comparable to those available for the Hutterites or other reference sets. More details on data quality and consistency on levels and trends in fertility in African DHS surveys can be found elsewhere. [Garenne & van Ginneken, 1994; Garenne 2008].

African populations were compared with the Hutterites, the main reference population used in demography. One could also compare African fertility profiles with other well documented populations in natural fertility situations, such as the Malay workers of the Coco-Keeling Islands plantations. [Smith, 1960]. This small population of about 1000 persons also had high period fertility (TFR= 8.4) and cohort fertility (CFS= 8.5), relatively long birth intervals (28 months) despite high infant mortality, medium age at marriage (18.6 years), low proportion never-married (3.1%), low primary infertility (2.6%), and low secondary infertility up to age 40. It resembles, to a certain extent, the Kenyan case described above, however with lower fertility rates before age 20, and higher values of fertility rates at age 20-35, and therefore is more similar to that of the Hutterites. What characterized best the African populations was the very high fertility below age 20, the longer birth intervals, and the higher secondary infertility at an early age (30 years) and after four births.

This study was based on data pertaining to the 1960-2010 period, that covered by DHS surveys. However, fertility is still increasing in some cases in Africa, and might reach new records in the future. This is in particular the case of Congo-Kinshasa (RDC), where rural fertility is still increasing, and to a lesser extent of Chad, Zambia and Uganda where rural fertility stayed at very high levels. Whether we will see new records in the future remains an open question.

This study focused on rural areas, where fertility was consistently higher than in urban areas in African populations, and where contraceptive use was much less prevalent and occurred later in time. The study may therefore have missed some interesting cases of high fertility in urban areas before 1960 (before family planning programs), where health and nutritional status was probably better than in rural areas, and where one might have found other cases of record high fertility. However, none such case was documented in any demographic survey available in Africa.

These findings have some implications for modeling the fertility schedule. The model of natural fertility derived from the Hutterite experience starts at age 18, whereas in Africa fertility starts already at age 12 in most DHS surveys, and in fact most censuses include births down to age 12 years. The age band between 12 and 18 years does not exist in the Hutterites reference model, so natural fertility has to be derived independently. One way of completing the model is to draw a line from 0 at age 12 to the value of marital fertility at age 18 found among the Hutterites. This strategy could be probably further refined by analyzing in-depth marital fertility in this age group in other populations, especially those with outstanding fertility.

The focus of this study was on empirical evidence of period fertility, whereas many historical studies on natural fertility deal with the theoretical model of

marital fertility (assuming that all women marry at exact age 18). This was a deliberate choice for shedding light on the functioning of the fertility regimen in Africa, in particular the very early age at marriage. In any case, the comparison of marital fertility between African and European populations raises a serious issue: that of taking into account the age at marriage, legal, religious or traditional. How to compare two populations if one allows marriage at age 12 and the other at age 18? If age 18 is selected, why ignoring what is happening before this age?

This remark calls for more attention on the concept of 'natural fertility', already extensively discussed. [see in particular van de Walle 1988]. Beyond the well documented physiology (fecundability, primary and secondary infertility, post-partum amenorrhea, breastfeeding, etc.), 'natural fertility' describes the situation of populations who do not limit their family size. It is typically a 'population' concept, more than an 'individual' or 'couple' concept, because in any population there will always be a few couples who, for any reason, will control their fertility, one way or another (separation, traditional methods of contraception, induced abortion, etc.). What characterizes societies in natural fertility situations is the absence of family limitation at population level. This situation is well described statistically by a variety of indicators such the age at last birth, contraceptive prevalence, the 'm' parameter in Coale and Trussell model of fertility rates, parity progression ratios, fertility rates by age and parity, etc. Note that virtually none of these parameters can be considered as a definite proof of family limitation, since biological secondary infertility can have the same demographic effect as birth control, with the possible exception of age at last birth which appears quite robust to extensive testing. A mean age at last birth close to- or higher than- 40 years is invariably associated with lack of family limitation at population level. However, this might change in the future in societies where fertility is delayed, and where the age at first birth is well above 30 years. Note also, as Dupâquier wrote earlier [Dupâquier 1984], that the wording of "natural fertility" is unfortunate, since traditional societies have put much emphasis on reproduction through the institution of marriage and the value of stable unions (the family), abundant offspring and child care. Prehistoric societies documented in the 20th century, such the Dobe !Kung of the Kalahary, seemed to have had very different social organization and different values with respect to reproduction, stable union and sexual behavior. [Howell 1979]. What is called 'natural' is in fact eminently 'social', even though constrained by biology. This is certainly the case in both African populations studied here, where social pressure for early marriage and reproduction is obvious, and where there is no statistical evidence of family limitation. The strategy of maximizing fertility through very early marriage could be justified for resisting to severe living conditions and uncertainty. [Hayford & Agadjanian 2011].

One could question the 'natural fertility' situation of the two African populations described. Firstly, a TFR of 9 or more children per woman and a CFS of 8 or more children per woman can be considered high enough to ensure that no family limitation existed in these populations since they are close to the maximum ever recorded. Secondly, a mean age at last birth of 39 or above can also be considered a proof of absence of family limitation at population level. Louis Henry proposed to use as a criterion of natural fertility that age specific fertility rates do not decline with parity. This criterion was tested in the case of Kenya and Niger, using the DHS datasets for the period of peak fertility. In regression analysis, parity did not appear to be a negative factor of fertility rates among women age 35-44 ($\beta = +0.0061$, $P = 0.719$ in Kenya; $\beta = +0.0762$, $P < 10^{-4}$ in Niger). However, this analysis requires a comment because of the interactions with secondary infertility: fertility rates were increasing with parity from 0 to 4 children ever-born, then slowly decreasing. When restricted to parity 4 and above, the relationship was negative in both cases, and significant in Kenya ($\beta = -0.1213$, $P < 10^{-5}$ in Kenya; $\beta = -0.0412$, $P = 0.104$ in Niger). This analysis is rarely done, and difficult to interpret because of the interactions with secondary infertility and selection biases. Data show that fertility rates at age 35-44 remained high even at high parities in both African populations, which is another indication of the absence of family limitation.

The issue of secondary infertility, and its factors, has been largely ignored in the literature on natural fertility. It has been described a long time ago in European populations [Vincent 1950], as well as in selected African populations [Antoine & Cantrelle, 1983]. It certainly deserves more attention, as it was a significant factor of fertility reduction in Kenya and Niger when compared with the Hutterites. High secondary fertility might be due to diseases, to nutritional status or to other unknown biological factors.

The two countries selected, Kenya and Niger, were on the top of the list of high fertility countries in Africa. However, some other countries could have qualified as well, with almost as high levels: Uganda, Zambia, Rwanda, and Burundi in Eastern Africa; Mali, Burkina Faso, Chad and Senegal in West Africa; some of the Coastal West African countries (Benin, Togo). Some other countries also present interesting features: Madagascar for instance had the largest

recorded parity in DHS surveys (21 children ever-born), and Ethiopia also has very high fertility associated with early marriage despite little polygamy. Lastly, fertility varies also by region and by ethnic group, and might exceed in certain cases the records presented in this study [Oyimloye et al. 2017]. These other cases deserve further attention and further research.

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