Fertility Transition in Sudan: An Application of Revised Mathematical Bongaarts Model

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Abstract

This paper aims to identify intermediate determinants, and to verify their impact on fertility in Northern Sudan, in light of a new vision and evidence.

There is a fertility decrease in Sudan. The (TFR) Total Fertility Rate has decreased by 23% during the period 1973 - 1999. We note that nuptiality had an important role in lowering of fertility during the specified period. The (C_m) index of marriage was 0.71 during Sudan Census 1973, 0.70 during the Sudan Fertility Survey 1979, 0.68 during the Sudan Demographic and Health Survey 1990, 0.65 during Sudan Census 1993 and 0.58 during the Safe Motherhood Survey 1999. Where we found that the three models (Original version by Bongaarts (1978), Revisions of Stover (1998) and Bongaarts (2015)) gave a very similar variation to the C_m index and the differences between Bongaarts and Stover models equal (0.66 versus 0.66), and slight differences simple in both (C_c) index of non-contraception and (C_i) index of lactational infecundability, where the difference between them in C_c value (0.94 versus 0.96), also C_i is worth (0.62 versus 0.61).

Keywords: *Sudan; Fertility; Bongaarts; Revised Model; Proximate Determinants*

Introduction

Recent stalls in fertility decline have been observed in a few countries in sub-Saharan Africa and so far no plausible common reason has been identified in the literature [1]. The situation of Arab States has been more bizarre than others[1] the results of the study showed that fertility rate in most countries of Sub-Saharan Africa depends on the progress in education, especially for women of primary school age during the 1980s. In contrast, fertility has been less prevalent in countries where the development of education has not reached advanced levels[2] as a situation of Arab countries, including Sudan, whereas the case of Sudan has been even more puzzling because women in the 1980s registering unusually high numbers of children.

[1]Some of the 22 Arab countries are in sub-Saharan Africa and follow the fertility pattern of the region.

[2]Goujon and Lutz and KC (2015). Education stalls and subsequent stalls in African fertility: A descriptive overview. Demographic Research, 33 (47). pp. 1281-1296. ISSN 1435-9871.

Looking at the region during the period 1980 - 1985, we find most women in the Arab countries had an average of 5.3 to 7.0 children, while in Sudan women registered an average of 4.6 children [2]. Researchers have assumed several hypotheses to explain the phenomenon of high fertility in the Arab region, including highlighting the specificity of Arab culture, and the role of Islamic religion [3], which has led to a demographic transition in the Arab region. Other researchers [4] found that the low levels of education and the low status of women could explain the high fertility rate, by the year 2015 the trend was clear towards reducing the number of children born to women, with an exception to some Arab least developed countries in Sub-Saharan Africa, including Sudan[3] , Iraq and Palestine in Middle East, and some Gulf countries where fertility rates are low, but given the number of indigenous people we will find it high. Fertility plays a very important role in demographic studies because it directly affects age and gender factors. In addition, information on population size and distribution is vital to development, strategic and economic planning. Fertility patterns in most African and Asian countries were very similar in the 1960s, where Total Fertility Rate (TFR) estimated at 6.6 children per woman and slightly higher than the average from low-income countries. In 1989, fertility levels in developing countries had varied markedly, these countries had seen some have reduced fertility by more than 50%, (TFR) registered 6.2 children per woman in 1965 to 2.7 kids per woman in 1989, and also the fertility rates in the United States began to decline in the 1960s and stabilized on a decline of 40% from 6.3 to 4.4 births per woman (Cohen, 1993). Sudan was one of the countries registered a clear decline of fertility, data showed a decrease in the total fertility rate from six births per women in 1979 Sudan Fertility Survey (SFS), to about five children in the 1990 Sudan Demographic and Health Survey (SDHS).

Fertility patterns and trends in Sudan

The population of Sudan reached 10.3 million in the first national census carried out in 1956 and the population growth rate was 2.2% per annum. Second census was conducted in 1973 and the total population was 14.8 million with a 2.2% per annum growth rate. At the 1983 census, Sudan's population reached 19.09 million. Estimated intercensal rate of growth, 1973 - 1983 was 2.8% per annum. Fourth population census was carried in 1993 and reported a total population of 24.24 million. Estimated intercensal growth rate 1983 - 1993 was 2.4% per year. The four national censuses reported a young age structure with about 45% of the population below the age of 15 and 3% of age 60 and over. Table 1 shows a good indicator of prevalence of high fertility. Regarding the dependency ratio, the four censuses reported respectively 105, 102, 98.8 and 102. The first census showed a crude birth rate of 51.7. The second population census reported

Age Group	SFS_{79}	$SDHS_{90}$	SMS_{99}	$MICS_{014}$	% change (79-90)	% change (79-99)	% change (90-99)	% change (99-2014)
15-19	114	69	72	87	-39.5	-36.8	4.3	20.8
20-24	264	183	187	207	-30.7	-29.2	2.2	10.7
25-29	283	240	233	259	-15.2	-17.7	-2.9	11.2
30-34	251	236	227	226	-6.0	-9.6	-3.8	-0.4
35-39	149	157	158	160	5.4	6.0	0.6	1.3
40-44	108	82	77	71	-24.1	-28.7	-6.1	-7.8
45-49	35	25	31	23	-28.6	-11.4	24	-25.8
	6.0	4.96	4.90	5.2	-17.3	-18.3	-1	6.1

Table 1: *$ASFR_S$ and TFR_S estimated for five-years period preceding (1979 - 2014) in Sudan.*
Source: SFS 1979 Principal Report I, SDHS 1990 Report I, SMS 1999 Report and MICS 2014.

[3]Comoros, Djibouti, Mauritania, Somalia, Sudan, and Yemen.

a crude birth rate of 48.8for the whole country, a mean of 4.8 children born to women (15 - 49 years) and a nationwide fertility rate of7.3 births per woman. The second and third population censuses reported a 6.7 and 6.8total fertility rates (TFRs) respectively. Fourth census showed the mean number of children ever born to all women was 6.5and a TFR of 5 children per woman.

When the Demographic Health Survey (DHS) data was compiled between 1990 and 1995 and analyzed, it was found that most of the countries in Sub-Saharan Africa had a TFR of more than 6 children per woman [5], despite these high fertility rates decrease and this decrease was documented in the number of countries in Africa, including Sudan (Cohen, 1993). Sudan is one of those countries that have undergone fertility decline. Recently, some evidence showed that the total fertility rate decreased from 6 children per woman in (SFS_79) (Sudan Fertility Survey) to about 5 children per woman in (SDHS_90) (Sudan Demographic Health Survey). For long periods of time, women in Sudan did not use contraception among the population as a Survey of Maternal and Child Health (SMCH, 1993), Through this survey, the proportion of women who did not use contraception has been registered by 9.9%, while the percentage of users during that period was about 5%. If the levels of these ratios are compared with SFS [6], there is a decrease in all levels. Women who did not use any method of contraception were about 12.3% while women who use contraceptive methods were about 6.4%.

Estimates of $ASFR_S$ and TFR_S were represented in table 1, TFR declined during the period between (1975-79) and (1986 - 1990) by 17.6% from 6.02 to 4.96 children, for the same period except "the women in the age group (35 - 39)", There is a decrease in fertility among women in the age cohorts, the largest decline in fertility in the age group (15 - 19) was 39.5%, while women in the age group (20 - 24) were about 30.7%. Fertility in the age group (35 - 39) rose by 5%, Fertility in the periods (1986 - 1990) and (1994 - 1999) has been low in most age groups.

In the other side fertility shows decline in periods (1975 - 1979) and (1995 - 1999), where the fertility rates of $ASFR_S$ in SFS_{79} are less than SMS_{99} except in the age group (35 - 39) years, generally TFR declined by 18.3%.

Intermediate fertility variables

Intermediate fertility variables are biological and behavioral factors through economic, social and cultural factors as well as environmental variables that affect fertility. These variables are called intermediate fertility variables. This term was first mentioned by Davis and Blake [7][4] . These are the relationships summed up by Bongaarts in the late 1970s, of the model of the relationship between four intermediate variables of fertility:

$TFR= C_m * C_c * C_a * C_i *TF$

TFR = total fertility rate, equal to the number of births a woman would have at the end of the reproductive years.

C_m = index of proportion married.

The index is calculated as a weighted average of the age groups of the percentages of Married women m(a), where (a)= age.

This indicator is calculated according to the following equation:

Equation (1) can also be written as C_m= TFR/TM, so that

$TFR= C_m *TM$ (2)

[4]Kingsley Davis and Judith Blake. "Social Structure and fertility: An analytic Framework". Economic Development and Cultural Change 4.4 (July 1956): 211-235.

TM = total marital fertility rate, equal to the number of births a woman would have at the end of the reproductive years if she were to bear children at prevailing age-specific marital fertility rates and to remain married during the entire reproductive period (based on the fertility of married women aged 15 - 45);

$TM= C_c*TNM$ (3)

Where

C_c≡ Index of non-contraception;

TM≡ Total marital fertility rate;

TNM≡ Total natural marital fertility rate, equal to TM in the absence of contraception and induced abortion;

$C_c=1-1.08\ u\ e$(4)

Where

u≡ Average proportion of married women currently using contraception (average of age-specific use rates);

e≡ Average contraceptive effectiveness (average of use-effectiveness levels by age and method).

1.08 = sterility correction coefficient;

We also find that bongaarts focused its discussion on the effect of contraception on marital fertility, to link the indicator of non-contraception to the total fertility rate, equation (3) is substituted in equation (2), to produce the following equation:

$TFR= C_m*C_c*TNM$ (5)

Bongaarts explained that effective Induced abortion measurement tools are somewhat lacking. The most detailed studies of this topic have been made by Robert Potter[5] . Where he showed in his work the following:

- An induced abortion always averts less than one birth.
- The number of births averted per induced abortion is largely independent of the age of the woman.
- The number of births averted per induced abortion is strongly influenced by the practice of contraception following the induced abortion. In the absence of contraception, an induced abortion averts about 0.4 births, while about 0.8 births are averted when moderately effective contraception is practiced. In general from the concept has been circulated to infants, the births averted per induced abortion, (b), may be estimated with the equation: $b=0.4(1+u)$ (6).

Bongaarts identified (A) as an overall measure of the incidence of induced abortion is provided by the total abortion rate

$A=b*TA= 0.4(1+u)*TA$ (7)

Where

A≡ The average number of births that have been averted per woman by the end of the reproductive years;

[5]Robert G Potter. "Additional births averted when abortion is added to contraception". Studies in Family Planning 7.8 (August 1976): 224-230.

Bongaarts also noted that induced abortion among the population is defined as a ratio between the total fertility rate of, TFR and the total fertility estimated without induced abortion TFR+A.

$$C_a = \frac{TFR}{TFR+A} \quad (8)$$

Where

C_a=The proportion by which fertility is reduced as the consequence of the practice of induced abortion.

According to the equation between TFR and TNM, modifying equation (5) to becomes now[6] :

TFR= C_m*C_c*C_a*TNM (9)

Bongaarts's vision in Lactational Infecundability C_i is that breastfeeding has a significant effect in increasing the period of birth and reducing natural fertility, by Comparing average length of period between pregnancy and the subsequent pregnancy in the case of breastfeeding or not, so the period of birth (pregnancy and other pregnancy) has been divided into four components[7] :

- An infecundable interval immediately following a birth. In the absence of lactation, this segment averages about 1.5 months, while prolonged lactation results in infecundable periods of up to two years. The duration of this birth-interval segment is usually measured from birth to the first postpartum menses, because the return of menses closely coincides with the return of ovulation.
- Waiting time to conception, which starts at the first ovulation following birth and ends with a conception? Although few measurements are available, existing observations indicate that population averages for this interval range from a low of about 5 months to high values that only rarely exceed 10 months, with typical values around 7.5 months[8].
- Time added by spontaneous intrauterine mortality. In cases where a conception does not end in a live birth, the duration of a shortened pregnancy and another waiting time to conception are added to the birth interval. On average the time added by intrauterine mortality equals about 2 months per birth interval.
- A nine-months gestation period ending in a live birth.

In the case of non- lactation, Bongaarts also stated that the standard average period of birth can be estimated to equal20 months as follows: 1.5 + 7.5 + 2 + 9 - 20 months, In the case of lactation it equals the average total duration of the infecundable period plus 18.5 months (7.5 + 2 + 9).

The average period of birth (by lactation and without and with lactation) is called lactational Infecundability:

$$C_i = \frac{20}{18.5+i} \quad (10)$$

[6]It should be noted that changes in the incidence of induced abortion will affect the index 〖C〗_m because it is calculated from the age-specific marital fertility rates, which are influenced by the practice of induced abortion. However, this effect is usually unimportant since proportional changes in the values of these marital fertility rates have an equal effect on the numerator and denominator of equation (1).

[7]Robert G Potter., et al. "A case study of birth interval dynamics". Population Studies 19.1 (July 1965): 81-94.

[8]Henry Leridon, Human Fertility: The Basic Components (University of Chicago Press, 1977).

Where

C_i=index of lactational infecundability;

i=average duration (in months) of infecundability from birth to the first postpartum ovulation (menses).

Bongaarts also found that the relationship between lactation and the natural marital fertility rate could be represented by the following equation:

TNM= C_i* TF (11)

Where

TF≡ total fecundity rate equal to the total natural marital fertility rate in the absence of lactation.

Given the equations (10) and (11) and in the absence of lactation, (i=1.5) month and thus the (C_i=1). This results in equal total fertility rate TF with the total natural marital fertility rate TNM, i.e. that TNM=TF.

If the average interval of non-Reproductive (i=18.9), it gives the value of index of lactational infecundability equal to C_i=0.53 and is also taken into account that TNM=0.53×TF.

The fertility impact on proximate determinants with revisions

If we return to the original model, which has several revisions, which represents this equation:

TFR= C_m C_c C_i C_a TF

The model treated each approximate PD as a fertility inhibitor, and each indicator has values in the range (0-1) based on the degree of fertility prevention (i.e. preventing each specific fertility). Index of marriage C_m measures the impact of the proportion of women in a marital relationship (e.g. formal marriage or informal consensual marriage) and the value of the indicator is one when all women are cohabiting and the index value is zero without cohabitation, assuming that women's sex practices in the marital relationship expose them to the risk of pregnancy.

The value of the contraception indicator C_c is one when there is no contraceptive use, and the index value is zero when all women have fertility using a 100% effective contraceptive.

Index of Lactational Infecundability C_i, this indicator is worth one in the absence of menstruation due to lactation or abstinence from postpartum cohabitation.

Index of abortion C_a equals one in the absence of abortion and zero in the case of abortion.

The total fertility rate (TFR) is the fertility rate that is supposed to be observed in the population with all the effects of fertility prevention in relation to approximate variables, and when:

C_m= C_c= C_i= C_a=1

The TF values are typical and standard for the rate of 15 children per woman[9] .

[9]John Bongaarts (2015). "Modelling the fertility impact of the proximate determinants: Time for a tune-up" Demographic Research: Volume 33, Article 19.

Bongaarts and Potter (1983) proposed an age-specific model of approximate determinants which is the version of the age cohorts of the approximate model, although the applications of age classification models are limited because they require a lot of data. After summarizing the model, it was found that the age-group equations of the indicators had the same structure that were not different, and had a clear advantage over the simple aggregated models and were taken to calculate the difference in age structures [8]. The original model also needed over time to be modified by Stover [9], where his adjustments provided detailed discussions of a number of issues and suggested revisions and several ideas on the coefficients to calculating for indexes. The proposal is summarized in the table 2 of the original model of approximate determinants by age-specific and indicator equations as follows.

	Equations	Variables
Original age-specific model	$f(a)= C_m (a) C_c (a) C_i (a) C_a (a) f_f (a)$	f(a)= age-specific fertility rate f_f (a)= age-specific fecundity rate a =age
Marriage index	$C_m (a)=m(a)$	m(a)= proportion married
Contraception index	$C_c (a)=1-r(a)u(a)e(a)$	u(a)= contraceptive prevalence (married women) e(a)= average effectiveness r(a) =fecundity adjustment
Postpartum infecundability index	$C_i(a) = \frac{20}{18.5 + i(a)}$	average duration of postpartum infecundability
Abortion index	$C_a(a) = \frac{f(a)}{f(a) + b\, ab(a)}$	ab(a)= abortion rate b=births averted per abortion

Table 2: *Original age-specific proximate determinants model and equations for indexes.*

Source: John Bongaarts (2015). "Modeling the fertility impact of the proximate determinants: Time for a tune-up" Demographic Research: Volume 33, Article 19.

The revised equations for the model of the approximate determinants have been developed by Bongaarts, according to age classification, and he explained that the calculation of these indexes requires the following variables:

m(a)= Proportion married/in union

ex(a)= Extramarital sexual exposure

u(a)= Contraceptive prevalence (among sexually active women)

o(a)= Contraceptive prevalence that overlaps with postpartum Infecundability

e(a)= Average contraceptive effectiveness

r(a)= Fecundity adjustment i(a)= average duration of postpartum infecundability

f(a)= Fertility rateab(a)= abortion rate

f_m (a)= f(a)/(m(a)+ex(a))= fertility rate among sexually exposed women

All of these variables {m(a), ex(a), u(a), o(a), e(a), r(a), i(a), f(a), f_m (a)} can be estimated from DHS surveys using procedures clarified by Bongaarts and Potter (1983) except two of which are r(a) and ab(a), where some discussions are required for possible estimation as they are explained about these two variables.

Index	Equations	Variables
	$f(a) = C^*_m(a)\, C^*_c(a)\, C^*_i\,(a) C^*_a(a) f^*_f(a)$	*represents revised measures
Sexual exposure index	$C^*_m(a) = m(a) + ex(a)$	m(a)== proportion married/union ex(a) =extramarital exposure
Contraception index	$C^*_c(a) = 1 - r^*(a)$ $(u^*(a) - o(a))e^*(a)$	u* (a)=contraceptive prevalence (exposed women) o(a)=overlap with postpartum infecundability e* (a)=average effectiveness r* (a)=fecundity adjustment
Postpartum infecundability index	$C^*_i(a) = \frac{20}{18.5 + i(a)}$	i(a)=average duration of postpartum infecundability
Abortion index	$C^*_a(a) = \frac{f(a)}{f(a) + b^*\, ab(a)}$ $b^* = \frac{14}{18.5 + i(a)}$	ab(a)= abortion rate b=number of births averted per abortion

Table 3: *Revised age-specific proximate determinants model and equations for indexes.*
Source: John Bongaarts (2015). "Modeling the fertility impact of the proximate determinants: Time for a tune-up" Demographic Research: Volume 33, Article 19.

Finally, bongaarts summed up the revised aggregate model in table 4, as well as, bongaarts summarized that the aggregate indexes in this model are weighted versions of the age-specific indexes and these weights vary by index, and the model equations are illustrated as follows.

Data and Method

The main sources of fertility analysis in Sudan are the Sudan Census (SC 1973) [10], Sudan Fertility Survey (SFS 1979) [6], the Sudan Demographic and Health Survey (SDHS 1990) [10], the Sudan Census (CS 1993), the Safe Motherhood Survey (SMS 1999) [11] and Sudan Multiple Indicator Cluster Survey (MICS 2014). The study makes use analytical procedures for proximate determinants that affect fertility with the original version by Bongaarts [12] versus the revised models by Stover [9] and Bongaarts (2015), with the proposed presentation on the model.

Results

Estimates of proximate determinants of each of the revised indexes were obtained from different sources for data in Northern Sudan as following.

Table 5 shows the values of indicators of the intermediate determinants and estimated and observed total fertility rates, after the application on (revised Bongaarts model) to the data, the results shows the most influential factor in fertility decline in Sudan during the period (1973 - 1999), which marriage age is delayed where (decreased from 0.71 to 0.60), then the contraception was where (declined from 0.96 to 0.88 in 1993 and then rose to 0.92 in 1999) and finally the least effective factor was natural breastfeeding.

Index	Equations	Variables
Revised aggregate model	$TFR = \sum C_m^*(a)C_c^*(a)C_i^*(a)C_a^*(a)f_f^*(a) = C_m^*C_c^*C_i^*C_a^*TF^*$	TF^*= revised total fecundity rate $f_f^*(a)$=revised fecundity rate
Sexual exposure index	$C_m^*(a) = \sum C_m^*(a) + w_m(a)$ $w_m(a) = \frac{f_m^*(a)}{\sum f_m^*(a)}$ $f_m^*(a) = C_c^*(a)C_i^*(a)C_a^*(a)f_f^*(a)$	$f_m(a)$= fertility rate, exposed women a =age
Contraception index	$C_c^* = \sum c_c^*(a)w_c(a)$ $w_c(a) = \frac{f_n^*(a)}{\sum f_n^*(a)} \approx \frac{f_f^*(a)}{\sum f_f^*(a)}$ $f_n(a) = C_i^*(a)C_a^*(a)f_f^*(a)$	$f_n^*(a)$= natural exposed fertility a =age
Postpartum infecundability index	$C_i^* = \sum C_i^*(a)\, w_i(a) \approx c_i$	
Abortion index	$C_a^* = \sum c_a^*(a)w_a(a) \approx \frac{TFR}{TFR + b^* TAR}$	TAR= Total abortion rate

Table 4: *Revised aggregate proximate determinants model and equations for indexes.*

Source: John Bongaarts (2015). "Modeling the fertility impact of the proximate determinants: Time for a tune-up" Demographic Research: Volume 33, Article 19.

			Data source		
Index	**SC (1973)**	**SFS (1979)**	**SDHS (1990)**	**SC (1993)**	**SMS (1999)**
C_m	0.71	0.70	0.68	0.65	0.58
C_c	0.96	0.96	0.94	0.88	0.92
C_i	0.62	0.63	0.60	0.61	0.64
C_a	1.0	1.0	1.0	1.0	1.0
Observed	6.8	6.02	5.0	4.6	4.7
Estimated	6.5	6.4	5.9	5.3	5.0

Table 5: *Indexes and total fertility rates Estimated and observed in the Sudan according to data sources (1973 - 1999).*

Source: Authors' calculation based on different data sources.

(Original model versus revised models) indexes

We'll encode (John Bongaarts revision) (JB) and (John Stover revision) (JS) in figures that will show the values of the revised indicators versus the original indicators.

Indicators and fertility rates	SC73	SFS79	SDHS90	SC93	SMS99	% change between (73-90)	% change between (79-93)	%change between (73-99)	%change between (93-99)
C_m	0.71	0.70	0.68	0.65	0.58	-4	-7	-18	-11
C_c	0.96	0.96	0.94	0.88	0.92	-2	-8	-4	5
Ci	0.62	0.63	0.60	0.61	0.64	-3	-3	3	5
Observed[1] TFR	6.8	6.02	5.0	4.6	4.7	-26	-24	-31	2
Estimated[2] TFR	6.5	6.4	5.9	5.3	5.0	-9	-17	-23	-6

Table 6: *Bongaarts indicators and their contribution to TFR change for the period between (1973-1999).*
Source: Authors' calculation based on different data sources.

Marriage index C_m

Since both Bongaarts and Stover take into account the issue of extramarital sexual activity, the revised models are the same as the original model because marriage is the only relationship that binds couples together and leads to having children, cases of having children outside the marital relationship rarely Occurs in Sudan and even it does exist it is not officially registered.

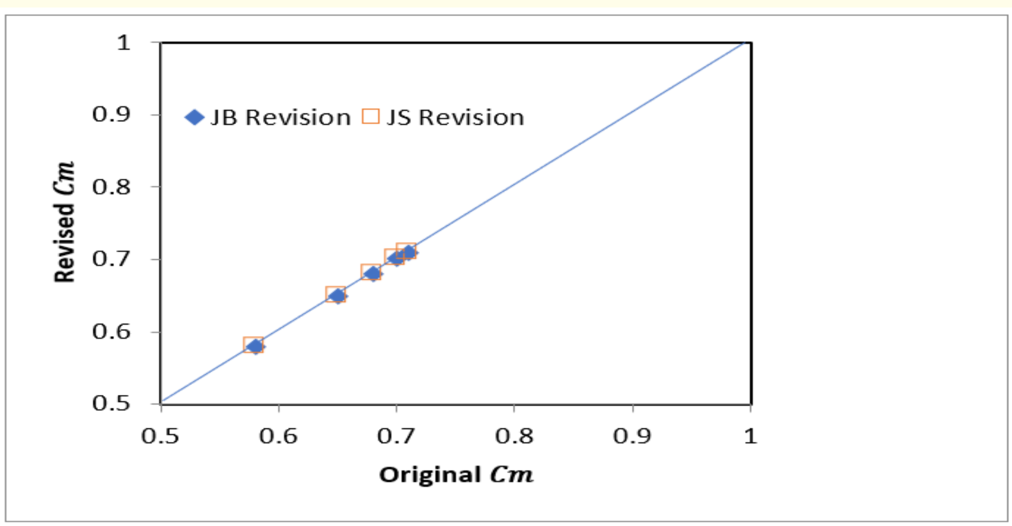

Figure 1: *Marriage Index, original model versus revised models.*
Source: Authors' calculation based on revisions.

Contraception index C_c

Since the fertility Adjustment Factor r(a) was developed to modify the contraception prevalence among married women, to calculate the higher fertility prevalence of low-fertility women, and to estimate this factor we applied a revised version of the method developed by Bongaarts and Kirmeyer [13], the method introduces a new variable f_nc (a) which is defined as the fertility rate of sexually exposed women, and can be observed in the absence of abortion and postpartum infertility as follows:

$$f_{nc}(a) = \frac{f(a)}{C_m^*(a)C_i^*(a)C_a^*(a)}$$

$$f_{nc}(a) = f_f^*(a)C_c^*(a)$$

As stipulated in the table of revised equations for the model of approximate determinants by age cohorts:

C_c* (a)=1-r* (a) (u* (a)-o(a))e* (a)]

Then

f_{nc} (a)=f_f* (a)[1-r* (a) (u* (a)-o(a))e* (a)]

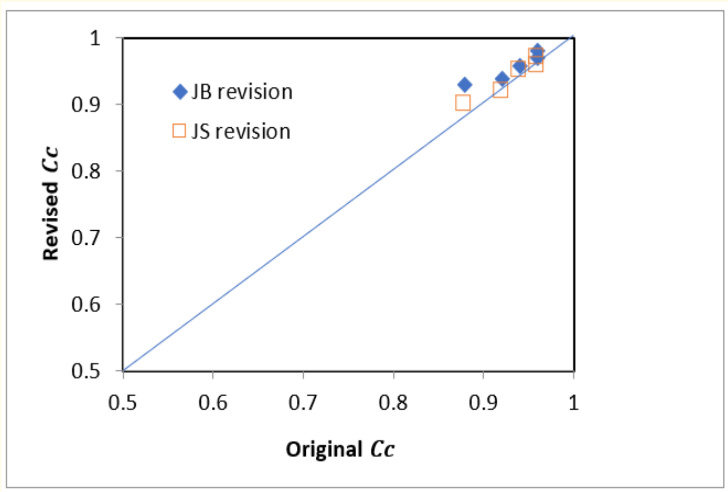

Figure 2: *Contraception Index, original model versus revised models.*
Source: Authors' calculation based on revisions.

Postpartum infecundability C_i

This indicator has not been revised and no observations have been made, but the nature breast-feeding index equations should be taken into consideration in the model of the specific age groups and at the aggregate model as illustrated in table 4 and 5.

The revised indicators estimate data obtained from various sources for the period (1973 - 1999) and attention was also given to summarizing the differences between the three models (the original model, the revised models).

Figure 2-4 indicate to (JS) and (JB) indicators versus the original model, and from the previous forms we note that the indicators are positively linked, and the strongest link observed in C_m, C_i, and then C_c.

In figure 2 we note that the issue of sexual intercourse is not permitted in Sudan, so the revised model indicators have been similar to those of the original form.

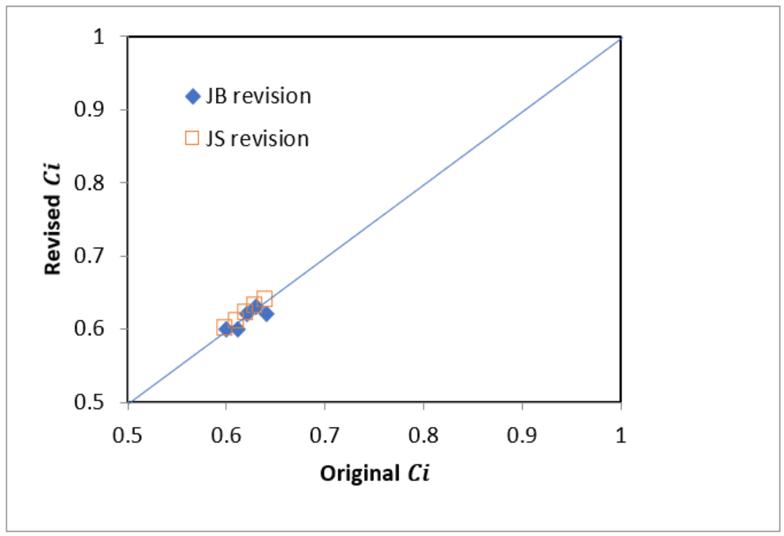

Figure 3: *Postpartum Infecundability original model versus revised models.*
Source: Authors' calculation based on revisions.

	C_m	C_c	C_i	C_a
Original model	0.66	0.93	0.62	1.0
JS Revision	0.66	0.94	0.62	1.0
JB Revision	0.66	0.96	0.61	1.0

Table 7: *Average of three model indicators in Sudan during the period (1973-1999).*
Source: Authors' calculation based on revisions.

In table 7, we find that the three models gave a very similar variation to the C_m index, and the differences between JS and JB models equal (0.66 versus 0.66), andslight differences simple in both C_c and Cɨ, where the difference between JS and JB models in the index C_c value (0.94 versus 0.6), in the C_i index is worth (0.62 versus 0.61).

This slight variation of the factors of religion and culture that exist in the Sudan can be attributed, if the models are applied in several states, there will hardly be differences in the factors of religion and culture, and therefore we will find very clear and significant differences in all indicators of the fundamental difference in the causes of these differences.

Figure 4-6 represent three indicator charts by TFR and as expected for C_m indicators and C_c decreases at different time intervals (data source surveys) and their higher-to-lower fertility transmission, the C_i indicator was fairly stable with higher-to-lower fertility movement as well.

Discussion

Since The original proximate determinants model by Bongaarts (1970) was found to have been widely used in fertility analysis. Our study is based on the assessment of the proximate determinants of fertility and the role of the selected socio-economic variables in in-

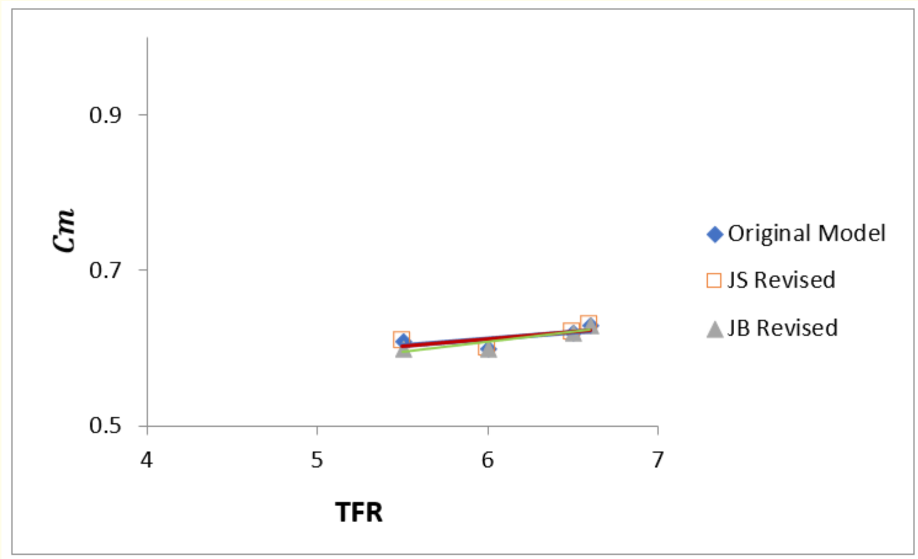

Figure 4: *Marriage index at the fertility rate.*
Source: Authors' calculation based on table 7.

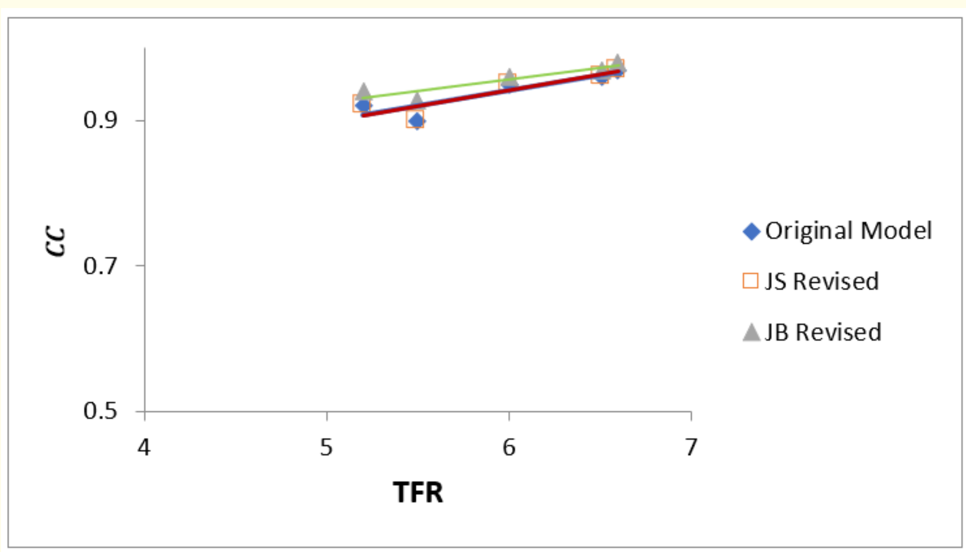

Figure 5: *Contraception Index at the fertility rate.*
Source: Authors' calculation based on table 7.

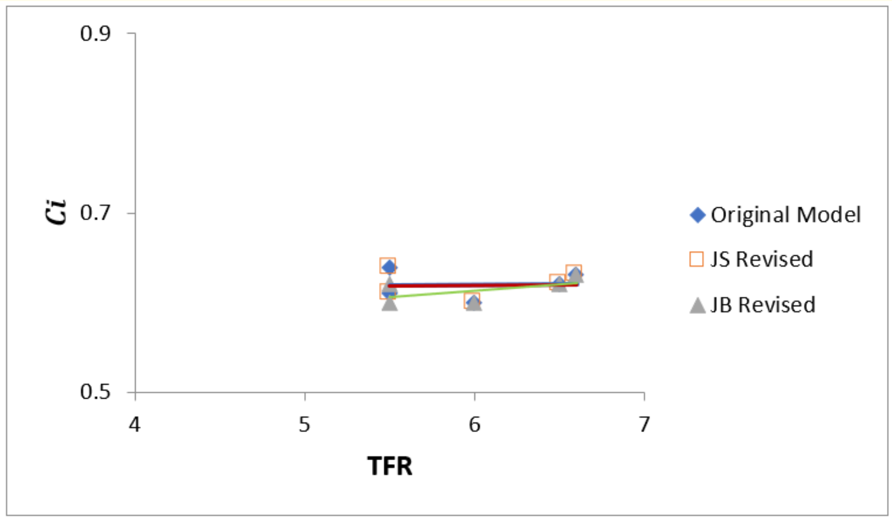

Figure 6: *Postpartum Infecundability at the fertility rate.*
Source: Authors' calculation based on table 7.

fluencing the proximate determinants and fertility in Northern Sudan. Six adjustments are proposed and implemented in this study on Sudan data. Compared with the original model and the revisions proposed by Stover [9] and Bongaarts (2015). The new revised model gives more accurate results to the (TFRs)in different data surveys [14-23].

Conclusion

We found that the three models (Original version by Bongaarts (1978), Revisions of Stover [9] and Bongaarts (2015) gave a very similar variation to the C_m index, and the differences between Bongaarts and Stover models equal (0.66 versus 0.66), and slight differences simple in both (C_c) index of non-contraception and (C_i) index of lactational infecundability, where the difference between them in C_c value (0.94 versus 0.96), also C_i is worth (0.62 versus 0.61).

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