BIOLOGICAL AND BEHAVIOURAL DETERMINANTS OF FERTILITY IN NIGERIA: AN APPLICATION OF THE REVISED BONGAARTS MODEL

Edifofon Akpan[1 2], Chidimma Oli[1], Abdulafeez Adefabi[1], Ezekiel Baiye[1]*, Olumide Taiwo[1 2]

[1] Helpman Development Institute, Abuja, Nigeria.
[2] Centre for Health Economics and Development, Abuja, Nigeria
[*] Corresponding author. Helpman Development Institute, 12 XXXXXXXXX Street Abuja, Nigeria. E-mail: ebaiye@helpmaninstitute.org

1. INTRODUCTION

Global population is expected to rise from 7.7 billion in 2019 to 8.5 billion in 2030, approaching 11 billion by the middle of the 21st century (Department of Economic and Social Affairs, 2019). This increase is a function of fertility, mortality, and migration, the principal determinants of population growth (Sloggett, 2015). While women in many parts of the world have had fewer children over the past few centuries (Lee, 2003), high fertility rates persist in sub-Saharan Africa despite different interventions (Babalola et al., 2019). By 2050, it is projected that up to half of the total population increase globally will be observed in these countries with lifetime fertility to remain well above two births per woman while many countries in sub-Saharan Africa are projected to double their population within the same period (Department of Economic and Social Affairs, 2019). Therefore, the speed of fertility decline in sub-Saharan Africa is a major determinant of global population prospects.

Nigeria is in the top-ten most populated countries globally, and like many sub-Saharan Africa countries is experiencing rapid population growth (Department of Economic and Social Affairs, 2019; Mberu & Reed, 2014). The country is in the early stage of demographic transition where fertility levels decline rather slowly as mortality falls significantly causing rapid population growth (Feyisetan & Bankole, 2009; Ifelunini et al., 2018). Given the established inverse relationship between economic development and fertility (Akpa, Onoja Matthew, & Ikpotokin, 2012; Lee, 2003; Lesthaeghe, 2010), substantial fertility reduction is critical to the subregion's demographic dividend. A low fertility rate is critical for reducing population growth while also improving socioeconomic and health outcomes (Sinding, 2009).

The primary indicator of fertility levels is the total fertility rate (TFR), a value that represents the average number of children a woman would bear in her lifetime based on current age-specific fertility rates. The 2018 Nigeria Demographic and Health Survey (NDHS) estimates Nigeria's TFR at 5.3 children per woman (National Population Commission & ICF International, 2019). The decline in Nigeria's TFR has been slow. From a high of 6.0 children per woman in 1990, it stalled at 5.7 in 003 and 2008, and 5.5 in 2013 (Federal Office of Statistics & IRD/Macro International, 1992; National Population Commission & ICF International, 2014; National Population Commission & ICF Macro, 2009; National Population Commission & ORC/Macro, 2000; National Population Commission & ORC Macro, 2004). Cultural and socioeconomic differentials in the TFR trend exist and mean the decline has been uneven. with a larger family size more desired in the north than the south (Adebowale, 2019). A study in Kaduna State reported less than 20% of women wanted less than 5 children and 69% citing 5-14 children as ideal (Adiri et al., 2010). This difference in fertility pattern can be attributed to early marriage prevalent in the Northern part of Nigeria (Goldstone et al., 2018; Solanke, 2015). In addition to the geographical disparity, there are considerable differences in rates among ethnic and socioeconomic groups (Mberu & Reed, 2014). TFR rates are lower among women who live in urban areas, women who have a secondary school education, and women who belong to households in higher or highest wealth quintiles (Wusu & Isiugo-Abanihe, 2019).

Demographically observed fertility or infertility is the result of a well-defined number of factors, collectively termed proximate determinants of fertility (Bongaarts, 1978; Bongaarts &

Potter, 1983). These proximate determinants serve to mediate the influence of culture, socioeconomic conditions, and related background determinants on reproductive behaviour. They could be grouped into biological and behavioural factors (Bongaarts, 1993). The biological constraints include pregnancy, period after delivery before fecundity resumes, waiting time to conception, time lost due to naturally occurring intra-uterine mortality, and time lost because of sterility. The behavioural component includes extent of sexual exposure, breastfeeding practice, use of a contraceptive method, and induced abortion. John Bongaarts first designed a quantitative framework for analysis which indicates that variations in four major factors – marriage, contraception, breastfeeding practice, and induced abortion – were the primary proximate causes of differences among populations (Bongaarts, 1978). Revisions of this framework have modified or added to these determinants (Bongaarts, 2015; Stover, 1998).

Studies conducted have identified various trends of fertility but similar differentials across sub-Saharan. A study across 13 countries found that non-marriage, post-partum amenorrhea and contraceptive use had substantial impacts on fertility reduction (Johnson et al., 2011). Additionally, higher education levels and urban residence were consistently associated with lower fertility rates. Findings from Uganda indicate that the use of contraceptives, marital status and mother's educational status were important predictors of fertility outcomes (Rutaremwa et al., 2015). In Zambia, earlier studies attributed the highest inhibiting fertility effect to be postpartum infecundability (Dzekedzeke & Nyangu, 1994), while a more recent study reported marriage to be the most inhibiting effect in the country (Chola & Michelo, 2016). In Ethiopia, non-marriage in 2011 and postpartum infecundability in 2016 had the highest fertility inhibiting effects (Laelago et al., 2019). In Namibia, the findings were very different: Contraceptive use appeared to have the highest inhibiting effect followed by non-marriage while breastfeeding was the least (Palamuleni, 2010). In summary, the relative contributions of biological and behavioural determfactors to inhibiting fertility across sub-Saharan appear to be context-specific.

Early studies on fertility in Nigeria have estimated exposure to the risk of childbearing through first marriage to be the most important proximate determinant followed closely by breastfeeding and postpartum sexual abstinence (Chimere-Dan, 1990; Jolly & Gribble, 1993; Odimegwu & Zerai, 1996). Socio-economic and cultural characteristics that have been proven to explain fertility differentials are education, female labour force participation, residence, household wealth, caesarean birth, cultural norms often measured by religion or ethnicity (Akpa, Onoja Matthew, & Ikpotokin, 2012; Alaba et al., 2017; Wusu & Isiugo-Abanihe, 2019). Female education has consistently been inversely related to fertility in Nigeria; women with a higher level of education tend to have a lower number of children ever born (CEB) than those with primary or no education (Alaba et al., 2017; Mberu & Reed, 2014; Opaneye, 1990; Wusu & Isiugo-Abanihe, 2019). The lowest fertility rate commonly reported in the south-west region, was due to the low numbers of uneducated women (Akpa, Onoja Matthew, & Ikpotokin, 2012).

The government of Nigeria formulated the nation's first population policy in 1988, titled the "National Policy on Population for Development, Unity, Progress and Self Reliance", which seeks to reduce fertility from the prevailing level of 6 children/family to an average of 4

children/family (Federal Republic of Nigeria, 1988). The policy suggests an optimum marriage age of 18 years for women and 24 years for men, and advocates that pregnancies be restricted to the 18-35-year range and at intervals of 2 years. New national population concerns and resolutions from the 1994 International Conference on Population and Development (ICPD) created a need to revise the 1988 policy. A revised NPP was launched in 2005 with, the demographic objectives of reducing national population growth rate to 2 % or lower by 2015, reducing total fertility rate by at least 0.6 children every five years and increasing modern contraceptive prevalence rate by at least 2 % per year (Federal Republic of Nigeria, 2005). More than 14 years after launching the NPP, Nigeria has experienced limited progress with TFR decreased by just 0.4 children (National Population Commission & ICF International, 2019). Nigeria's population growth rate is still very high and is considered one of the highest in the world. By its end date, the policy failed to achieve its aspirations (National Population Commission & Health Policy Project, 2015)

With growing concerns about Nigeria's population explosion among observers and policymakers, it has become necessary to conduct studies focused on trends and how background factors have influenced fertility through the proximate determinants. This is especially important with the heightened campaigns on sexual abstinence, contraception use, and breastfeeding (National Population Commission & ICF International, 2014). In this study, we examine trends in the determinants of fertility along with trends in geographical and socioeconomic correlates using a revised Bongaarts model. We also assess how changes in these factors over time may have influenced changes in the effects of proximate determinants on fertility. Finally, we reflect on the key outcome indicators by examining women's reproductive options alongside maternal and child health policy priorities. By providing insights into fertility dynamics and possible points of programmatic intervention, we hope to inform fertility-related population policy priorities.

2. METHODS

2.1 Data Sources

We used data from the Nigeria Demographic and Health Survey of 2003, 2008, 2013 and 2018 for this study (National Population Commission & ICF International, 2014, 2019; National Population Commission & ICF Macro, 2009; National Population Commission & ORC Macro, 2004). These surveys were nationally representative survey of Nigerian households. Women aged 15-49 were eligible to be interviewed if they were either permanent residents or visitors who spent the previous night in the household. A total of 7,620; 33,385; 38,948 and 41,821 women aged 15-49 were interviewed in 2003, 2008, 2013 and 2018 surveys, respectively. The survey collected various information from women including fertility preference, sexual activity, and reproductive history, alongside background characteristics.

The key background variables considered in this study were percentage of women with secondary education or above, percentage of women working in the labour force, percentage of women living in urban residence, percentage of women in different geographical zones. The TFR *was* calculated from births and exposure during the three years (36 months) prior to each woman's month of interview. The nominal date of a *TFR* is the year of the survey, but the

reference period is prior to that. The reference period for the proximate determinants is also prior to the date of interview except for contraception, which is based on current contraceptive use. In terms of synchronization, the link between fertility and contraception is problematic. For individual women, contraception affects subsequent fertility, but in the data, fertility s measured for an earlier date than contraception.

For the estimation of index of abortion, we used the total abortion rate (TAR) reported in a survey by Guttmacher Institute (Bankole et al., 2015). The survey estimated the TAR using data on delivery of abortion and post-abortion care services from a nationally representative sample of 772 health facilities in 2012. The TAR obtained from his study was kept constant for all years of the analysis – 2003, 2008, 2013 and 2018.

2.2 Data Analysis

This study examines the contributions of biological and behavioural determinants to fertility change, as well as the effects of the socio-economic and geographic factors through which the determinants exert their influence. Statistical analyses for inputs in the model were performed using Stata 16.0 (StataCorp) and confirmed with published DHS reports for inputs available in the reports. The proximate determinants of fertility, potential fertility and background variables were calculated using Microsoft Excel 2019 software. In the following section we present detailed analysis of fertility differentials that quantifies the negative and positive effects of each of the socio-economic and geographic factors on fertility through various intermediate fertility variables.

2.2.1 Proximate determinants: The Bongaart's Model

We used a revised version of Bongaarts' proximate determinants model to assess the relationship between projected potential fertility (PF) and behavioural and biological factors. Each of the determinants is assumed to independently inhibit fertility. In the original model, Bongarts identified the following: an index for marriage, contraception, abortion and post-partum infecundity and expressed TFR as the product of the four indices together with total fecundity (TF) - the average number of live births expected among women during their entire lifetime, (Bongaarts 1978).

$$TFR = Cm * Ci * Cc * Ca * TF$$

where, TFR is the total fertility rate, C_m is the index of proportion married, C_i is the index of post-partum infecundability, C_a is the index of induced abortion, C_c is the index of contraception. The indices only take values between 0 and 1. If the corresponding index is of no fertility inhibition effect, the index equals 1; an index of 0 which is not empirically proven, indicates total inhibition effect (Bongaarts, 1978). A revision of this model attempted to account for overlaps between the determinants, specifically between postpartum amenorrhea and contraceptive use (Stover, 1998).

The revised framework used for this study includes five intermediate fertility variables; proportion sexually exposed, postpartum infecundability, contraception, induced abortion, and sterility which are key direct determinants of fertility. From the original model, the index of marriage i was revised to include women who have been in a sexual union in the last month, use contraceptives, are pregnant or post-partum infecundable. This index was renamed index of sexual exposure (Stover, 1998). The index of post-partum infecundability was modified to

post-partum insusceptibility including both median duration of post-partum amenorrhea and post-partum abstinence. The index of abortion was revised by multiplying contraceptive prevalence with average use effectiveness of contraception (Stover, 1998). The index of sterility was modified from proportion of women 45-49 years old who had no live births to the proportion of sexually active women who are infecund. Index of contraception was revised to the proportion of sexually active fecund women using contraceptives that do not overlap with those experiencing postpartum amenorrhea and the average effectiveness of contraception (Stover, 1998). The revised equation relating the total fertility rate to the proximate determinants used in this study is expressed as

$$TFR = PF \times C_x \times C_u \times C_a \times C_i \times C_f$$

Where TFR is the total fertility rate, PF is the potential fertility, C_x represents the index of sexual exposure, C_u is the index of contraception, C_a is the index of induced abortion, C_i is the index of postpartum insusceptibility and C_f represents the index of sterility. Estimates from empirical data showed an average potential fertility of 21 (18-24) births per woman for the 35-year reproductive period from age 15 to 49 years (Stover, 1998). Nonetheless, estimates of PF may exceed its theoretical limits because of a large error term in the proximate determinants' framework, attributed in a large part to the effects of unmeasured factors exogenous to the framework (UN DESA Population Division, 2014).

2.2.2 The index of sexual exposure (C_x)

The index of sexual exposure expresses the reduction in fertility caused by women's not being sexually active throughout their entire reproductive period. The index is calculated as

$$C_x = s$$

where s is the proportion of women aged 15-49 who are sexually active (women who either are pregnant, report sex in the last month, use contraception, or are postpartum infecundable). The index of sexual exposure, C_x, equals 1 if all women of reproductive age are sexually active during the entire reproductive period and 0 in the absence of such.

The Index of Contraception (C_c)

This considers both the level of contraceptive prevalence and the average effectiveness of contraceptive methods used. It is estimated as:

$$Cc = 1 - 1.08ue$$

Where u is the proportion of women in the reproductive ages who are currently using contraception among those sexually active, excluding exclude those infecund and postpartum amenorrhic within 6 months after birth; and e is the average of use-effectiveness of contraception as practiced in the population. Estimates of the method-specific effectiveness are: sterilization (0.995), pill (0.930), injectable (0.970), implant (0.999), intra-uterine device (0.993), male condom (0.870), and other modern methods (0.800) (World Health Organization & Johns Hopkins CCP, 2017).

2.2.3 The index of abortion (C_a)

The index of abortion is the proportion by which the PF is reduced due to induced abortion. Births averted per induced abortion are related to contraceptive use (UN DESA Population

Division, 2014). The index of abortion is defined as the ratio of the observed TFR to the estimated TFR without induced abortion and declines with increasing incidence of induced abortion (Stover, 1998). This index is calculated as follows.

$$C_a = \frac{TFR}{TFR + 0.4 \times (1 + u) \times TAR}$$

where TFR is the total fertility rate, u represents the proportion protected by contraception among women who have an induced abortion and TAR is the total abortion rate which is the average number of induced abortions per married or in-union woman at the end of the reproductive period if induced abortions remain at prevailing levels. The index of induced abortion equals 1 in the absence of induced abortion and 0 if all pregnancies are aborted. Reliable data on the total abortion rate for all years is not available. We assumed abortion rates prevailing in 2012 (Bankole et al., 2015), will remain constant throughout 2018.

2.2.4 The index of postpartum infecundability (C_i)

The index of postpartum infecundability represents the reduced risk of exposure to conception immediately following a birth (Bongaarts & Potter, 1983). In the absence of any breastfeeding (and postpartum abstinence), the average birth interval is around 20 months, which includes four segments: a period of postpartum amenorrhea (1.5 months), the average waiting time to conception (7.5 months), time added by spontaneous intrauterine mortality (2 months) and 9 months of a full-term pregnancy. The last three segments are assumed constant and sum up to 18.5 months. Postpartum amenorrhea is extended by breastfeeding and abstinence. The index of postpartum infecundability is estimated by the ratio of the average birth interval where breastfeeding and abstinence are absent, and the length of a birth interval where the period of postpartum infecundability is extended by breastfeeding and abstinence. It is estimated using the formula.

$$Ci = \frac{20}{18.5 + i}$$

where C_i = index of postpartum infecundability; and i = average duration of postpartum infecundability due to breastfeeding and postpartum abstinence. In the absence of breastfeeding and abstinence, i would be equal to 1.5, its minimum possible value, and C_i would equal 1. As the duration of postpartum infecundability increases, C_i declines and it would tend towards 0 if the duration of postpartum infecundability were to continue indefinitely.

2.2.5 The index of sterility (C_s)

C_s measures the incidence of natural infertility and pathological sterility. This index expresses the total effect of infecundity because of a pathological condition. The net effect of pathological sterility would be the difference between the actual index and some base value that represents natural infecundity. The formula for measuring the index of sterility is represented as:

$$C_f = 1 - f$$

where f is defined as the proportion of sexually active women who are infecund.

2.3 Background and institutional factors

In this study, we assessed the socio-economic or contextual characteristics that influence fertility through changes in the proximate determinants. These were the level of education, female participation in the workforce, wealth quintile, geopolitical regions, and type of residence. Each of these factors has well established associations with fertility (Johnson et al., 2011). We examined fertility preferences through the ideal number of children and desire for more children. The DHS asks women with living children, *"If you could go back to the time [when] you did not have any children and could choose exactly the number of children to have in your whole life, how many would that be*?" For women who are yet to give birth, the question is framed as "*If you could choose exactly the number of children to have in your whole life, how many would that be*?" (National Population Commission & ICF International, 2019). We considered only numeric responses. The survey also asked women whether they wanted more children in addition to those they have, thus reflecting desire for further reproduction.

The study also tracked four indicators of women's fertility preferences. The key indicators that reflect fertility-related international policy and program priorities include planning status for most recent birth in the past five years, percent of children born to mothers under age 18, percent of children born to mothers over age 34, and the median length of the birth interval (in months). We assessed the strength of Nigeria's Family planning programs using the Family Planning Effort Index (FPEI) and National Composite Index on Family Planning (NCIFP). The FPE has been collected periodically since 1972, and provides results across four key components: policies, services, evaluation, and access (Avenir Health, 2017a). The index was developed to measure the level of effort that goes into FP programs, and to track how these changes over time. The NCIPF measures the existence and implementation of family planning policies and program under five components: strategy, data, quality, equity, and accountability. It is built on the FPEIS framework (Avenir Health, 2017b).

3. RESULTS

The indices of direct biological and behavioural determinants of fertility from Bongaarts models is shown in Table 1. The behavioural indices include index of sexual exposure (C_x), index of contraception (C_c) and index of abortion (C_a) while the index of sterility (C_s) is a biological determinant. Postpartum infecundability (C_i) is a function of the duration of postpartum amenorrhea and postpartum abstinence. The duration of amenorrhea is a function of the normal length of amenorrhea after childbirth women which is due to breastfeeding practices. The duration of abstinence is entirely behavioural.

Table 1: Estimated Indices for Proximate Determinants of Fertility, DHS 2003-2018

Year	Cx	Ci	Ca	Cf	Cu	PF	TFR (Survey)	TFR (Bongaarts)
2003	0.70	0.59	0.94	0.81	0.85	21.00	5.65	5.65
2008	0.70	0.62	0.94	0.82	0.82	20.72	5.72	5.80
2013	0.72	0.64	0.94	0.80	0.81	19.48	5.50	5.93
2018	0.68	0.64	0.94	0.80	0.82	19.61	5.29	5.67

Ci was the lowest among the indices in our study at 0.64 in the 2018 survey. This implies that postpartum infecundability is associated with reduction of potential fertility by 36% from its biological maximum. Delayed sexual exposure (Cx) inhibited fertility by 32% being the second most effective fertility reducing factor. The index of abortion was high at 0.94. (Awoyemi and Novignon 2014, Ibrahim and Onwudiegwu 2012, Lamina 2015). This index is therefore excluded from the discussions. The other reductions in PF occurred because of inability to bear children (Cf, 0.80) and effects from the use of contraceptive technologies (Cu, 0.82). The lowest contributor is the index of contraception, contributing to 18% reduction in PF. There were little changes during the period of the survey in the 5 indices.

The revised Bongaart's model gave an estimated TFR of 5.67, which is 0.38 children higher than TFR measured by DHS survey in 2018 (5.29). The analysis arrived at similar values for 2003 (5.65 each). Any difference between these sets of TFRs may be due to underestimation in DHS samples, inaccuracies in the data, lack of precision in our estimation of the indices, or other factors left out of the model. Nevertheless, the model shows the relative contributions of the determinants, and enables us report variations between socioeconomic and geographic groups, as well as changes over the years of the surveys 2003-2018.

The influence of the proximate determinants and their variability by these background factors are presented in tables 2, 3, 4 and 5 for 2018, 2013, 2008 and 2003 respectively. The study shows that for 2018, attainment of secondary education is associated with relatively low indices for sexual exposure (0.58) and contraception (0.62). Across the educational attainment levels, these two indices have an inverse relationship in all years of the survey. On the other hand, the index of postpartum infecundability increases with additional educational attainment. This would reflect shorter duration of breastfeeding which is essential to prolong duration of postpartum amenorrhea, and quicker cessation of sexual abstinence after delivery.

Concerning disparity in place of residence and wealth, Cx was higher among rural residents in all years (rural – 0.74, urban – 061). This means sexual exposure inhibited fertility by 33.5% among rural residents, and 39% among city dwellers. On the contrary, the Ci was higher among urban residents (rural – 0.61, urban – 0.68). Contribution of sterility to reducing PF is not dependent on place of residence, as Cf in all years were within $\pm$0.03 units. As expected, the index of contraception is higher in rural areas relative to urban population, reflecting a higher contraceptive use among sexually exposed female urban dwellers. There also are notable differences between women of different wealth quintiles. The values of the indices are lower for women in higher wealth quintiles, meaning a higher depression of fertility, with exception of Ci. The Ci increases progressively along the wealth quintiles (lowest – 0.56, second – 0.61, middle – 0.64, fourth – 0.68, highest – 0.75) in 2018, as well as across all the years of the survey.

Workforce participation is associated with a lower fertility in 2018, with no notable difference in preceding years. In the latest year of the survey, the estimated TFR among women in workforce was 5.22, compared to 5.93 in women without workforce participation. In 2013 however, the reverse was the case (in workforce – 5.76, not in workforce – 5.62) The differences were negligible in 2008 (in workforce – 5.93, not in workforce – 5.99), and 2003 (in workforce – 5.78, not in workforce – 5.74). In all years, the index of contraception contributed more to depression of fertility among those in workforce compared to those not

active in workforce. In contrast, the index of marriage and index of sterility contributed more to fertility reduction among women of reproductive age not active in workforce. The contributions of the index of postpartum infecundability and index of abortion were near identical.

Table 2: Estimated indices of proximate determinants of fertility 2018

Variables	**Cx**	**Ci**	**Ca**	**Cf**	**Cu**	**PF**	**TFR (Survey)**	**TFR (Bongaarts)**
Aggregate								
National	0.68	0.64	0.94	0.80	0.82	19.61	5.29	5.67
Education								
No education	0.83	0.58	0.95	0.78	0.91	20.57	6.74	6.88
Primary	0.69	0.63	0.94	0.75	0.69	27.65	5.81	4.41
Secondary/Higher	0.58	0.70	0.91	0.84	0.62	22.09	4.21	4.00
Residence								
Urban	0.61	0.68	0.92	0.80	0.59	24.82	4.50	3.81
Rural	0.74	0.61	0.94	0.80	0.81	21.45	5.94	5.82
Wealth quintile								
Lowest	0.79	0.56	0.95	0.81	0.91	21.44	6.70	6.56
Second	0.75	0.61	0.95	0.80	0.84	21.26	6.20	6.12
Middle	0.66	0.64	0.94	0.79	0.75	23.89	5.59	4.91
Fourth	0.63	0.68	0.92	0.80	0.61	23.63	4.55	4.04
Highest	0.61	0.73	0.90	0.80	0.54	21.82	3.79	3.65
Workforce								
In workforce	0.73	0.64	0.93	0.78	0.67	22.94	5.22	4.78
Not in workforce	0.58	0.63	0.94	0.86	0.84	23.68	5.93	5.26
Regions								
North Central	0.65	0.63	0.93	0.80	0.70	23.73	5.03	4.45
North East	0.73	0.62	0.95	0.82	0.84	20.60	6.06	6.18
North West	0.77	0.58	0.95	0.83	0.86	21.81	6.60	6.35
South East	0.55	0.69	0.92	0.77	0.56	31.44	4.72	3.15
South South	0.63	0.75	0.90	0.74	0.63	20.05	4.03	4.22
South West	0.63	0.68	0.91	0.80	0.53	23.24	3.86	3.49

Table 3: Estimated indices of proximate determinants of fertility (2013)

Variables	**Cx**	**Ci**	**Ca**	**Cf**	**Cu**	**PF**	**TFR (Survey)**	**TFR (Bongaarts)**
Aggregate								
National	0.72	0.64	0.94	0.80	0.81	19.48	5.50	5.93
Education								
No education	0.86	0.58	0.95	0.77	0.94	20.20	6.93	7.20
Primary	0.74	0.63	0.95	0.78	0.65	27.27	6.13	4.72
Secondary/Higher	0.59	0.72	0.91	0.86	0.50	24.79	4.21	3.57
Residence								
Urban	0.65	0.70	0.92	0.82	0.51	26.49	4.66	3.69
Rural	0.78	0.61	0.95	0.80	0.79	22.06	6.18	5.88
Wealth quintile								
Lowest	0.86	0.57	0.96	0.77	0.96	19.84	6.95	7.36
Second	0.78	0.58	0.95	0.80	0.87	22.13	6.72	6.38
Middle	0.67	0.64	0.94	0.80	0.71	25.14	5.68	4.74
Fourth	0.66	0.70	0.93	0.81	0.56	25.52	4.89	4.02
Highest	0.66	0.76	0.90	0.83	0.42	24.46	3.90	3.35
Workforce								
In workforce	0.79	0.64	0.94	0.78	0.63	24.55	5.76	4.93
Not in workforce	0.61	0.64	0.94	0.86	0.77	23.43	5.62	5.04
Regions								
North Central	0.65	0.63	0.94	0.82	0.68	24.63	5.28	4.50
North East	0.79	0.62	0.95	0.79	0.93	18.47	6.30	7.16
North West	0.83	0.58	0.95	0.79	0.87	20.75	6.68	6.76
South East	0.57	0.69	0.92	0.77	0.45	37.89	4.71	2.61
South South	0.66	0.76	0.91	0.81	0.49	23.60	4.27	3.80
South West	0.67	0.69	0.92	0.84	0.37	34.19	4.55	2.79

Table 4: Estimated indices of proximate determinants of fertility (2008)

Variables	**Cx**	**Ci**	**Ca**	**Cf**	**Cu**	**PF**	**TFR (Survey)**	**TFR (Bongaarts)**
Aggregate								
National	0.70	0.62	0.94	0.82	0.82	20.72	5.72	5.80
Education								
No education	0.85	0.57	0.96	0.77	0.94	21.80	7.29	7.02
Primary	0.71	0.63	0.95	0.82	0.72	25.95	6.49	5.25
Secondary/Higher	0.55	0.69	0.91	0.89	0.54	24.85	4.23	3.57
Residence								
Urban	0.65	0.70	0.92	0.84	0.56	23.71	4.71	4.17
Rural	0.73	0.59	0.95	0.81	0.79	23.83	6.28	5.53
Wealth quintile								
Lowest	0.83	0.56	0.96	0.80	0.94	21.29	7.12	7.02
Second	0.76	0.57	0.96	0.81	0.87	24.17	7.02	6.10
Middle	0.66	0.60	0.95	0.81	0.77	24.92	5.88	4.95
Fourth	0.64	0.69	0.93	0.84	0.60	23.92	4.96	4.35
Highest	0.64	0.75	0.90	0.86	0.47	22.79	4.04	3.72
Workforce								
In workforce	0.77	0.62	0.94	0.80	0.67	24.54	5.93	5.08
Not in workforce	0.60	0.61	0.95	0.87	0.77	26.24	5.99	4.79
Regions								
North Central	0.66	0.56	0.94	0.80	0.73	26.42	5.41	4.30
North East	0.81	0.59	0.96	0.80	0.93	20.97	7.16	7.17
North West	0.86	0.58	0.96	0.81	0.95	20.19	7.30	7.59
South East	0.51	0.73	0.92	0.80	0.57	31.08	4.82	3.26
South South	0.66	0.71	0.92	0.84	0.51	25.49	4.69	3.86
South West	0.64	0.65	0.92	0.84	0.49	28.48	4.52	3.33

Table 5: Estimated indices of proximate determinants of fertility (2003)

Variables	**Cx**	**Ci**	**Ca**	**Cf**	**Cu**	**PF**	**TFR (Survey)**	**TFR (Bongaarts)**
Aggregate								
National	0.70	0.59	0.94	0.81	0.85	21.00	5.65	5.65
Education								
No education	0.83	0.56	0.95	0.73	0.93	21.78	6.71	6.47
Primary	0.69	0.61	0.95	0.83	0.76	25.19	6.32	5.27
Secondary/Higher	0.56	0.75	0.91	0.91	0.60	20.12	4.24	4.43
Residence								
Urban	0.66	0.64	0.93	0.82	0.65	23.12	4.86	4.41
Rural	0.73	0.57	0.95	0.80	0.82	23.58	6.07	5.41
Wealth quintile								
Lowest	0.77	0.54	0.95	0.77	0.86	24.62	6.52	5.56
Second	0.77	0.56	0.95	0.78	0.87	22.76	6.30	5.81
Middle	0.69	0.57	0.95	0.79	0.84	23.28	5.70	5.14
Fourth	0.66	0.64	0.94	0.82	0.74	24.19	5.85	5.08
Highest	0.64	0.77	0.91	0.88	0.58	18.46	4.21	4.79
Workforce								
In workforce	0.77	0.59	0.95	0.79	0.73	23.23	5.78	5.23
Not in workforce	0.61	0.60	0.94	0.83	0.80	25.04	5.74	4.81
Regions								
North Central	0.60	0.53	0.95	0.81	0.71	32.48	5.70	3.69
North East	0.77	0.57	0.96	0.79	0.91	23.14	7.03	6.38
North West	0.87	0.59	0.95	0.78	0.93	18.66	6.69	7.53
South East	0.56	0.63	0.92	0.78	0.71	23.16	4.11	3.73
South South	0.63	0.72	0.92	0.84	0.58	23.13	4.63	4.20
South West	0.56	0.65	0.92	1.00	0.49	25.20	4.12	3.43

This study also attempts to examine the effects of inputs into Nigeria's family planning program on fertility reduction. The family planning effort index (FEPI) score increased between 1972 and 1999, then reduced through 2009, before increasing to 41% in 2014. The increase in FEPI to its all-time highest in 1999 corresponds to the lowest survey TFR recorded in Nigeria, 5.11 in 1999 (National Population Commission & ORC/Macro, 2000). During this time, access to contraceptives was high at 70.3%, and evaluation of services rendered stood at 81.4% (see Supplementary Information). The FEPI has since been replaced by another measure, the National Composite Index on Family Planning, NCIFP (see Supplementary Information). The most recent NCIFP in 2017 assessed the strategy (score – 62.4%), data (65.5%), quality (62.0%), accountability (39.0%) and equity (58.0%) of family planning in Nigeria. On all measures, the scores in 2017 (composite index – 62.4%) were higher than those in 2014 (composite index – 49.5%)

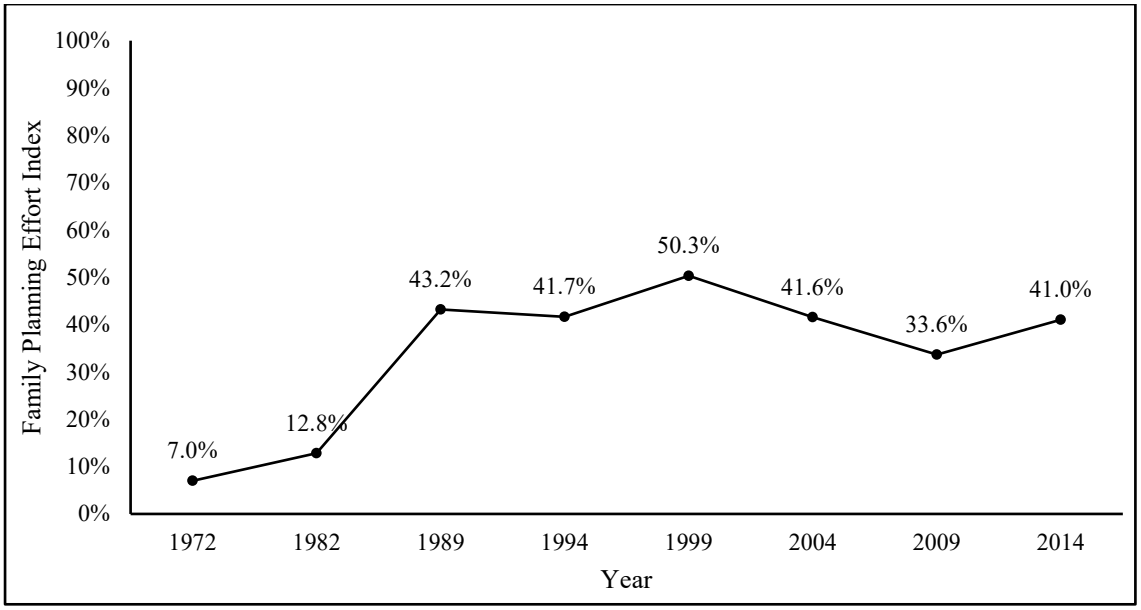

Figure 1: Nigeria Family Planning Effort Scores

This indicator is based on the aggregate of four dimensions of family planning effort (policies, services, evaluation, and method access). The raw scores were converted to percentages and are reported.

Lastly, the study includes some outcome indicators. The state of planning for new births and incidence of births among the young and aged population reflect policy priorities concerning reproductive options available to women. (Johnson et al., 2011). Among 12.2% of women aged 15-49 years with at least one child, the most recent birth was planned i.e., they wanted to have their last child at the time. There has been no notable increase in the median birth interval. The percentage of births to women less than 18 years of age has steadily reduced from 8.9% in 2003 to 6.0% in 2018. Overall, after an initial increase between 2003 and 2008, the percentage of births to women older than 34 years has remained relatively unchanged.

Table 6: Some Women Reproductive Options Outcome Indicators

Outcome Indicator	**Year of Survey**			
	2003	**2008**	**2013**	**2018**
Most recent birth was planned	16.7%	11.9%	9.8%	12.2%
Median birth intervals (months)	31.2	31.3	31.7	30.9
Births to women <18 years	8.9%	7.3%	7.1%	6.0%
Births to women >34 years	14.4%	15.3%	15.3%	15.0%

DISCUSSION

The revised Bongaarts model was used in this study to demonstrate the contributions of biological and behavioral determinants of fertility in Nigeria, as well as the effects of selected socioeconomic and geographical variables. The results specifically measured the effect of sexual exposure, contraception use, postpartum infecundity, abortion, and sterility on lowering a potential fertility level of 21 births per woman. From 2003 to 2018, postpartum infecundability was the most influential factor in reducing fertility, according to our findings.

Previous research in Nigeria (ChimereDan, 1990; Jolly & Gribble, 1993), Ethiopia (Alene and Worku, 2009; Mekonnen and Worku, 2011; Mekonnen and Worku, 2011; Palamuleni, 2010),

and Kenya (Alene and Worku, 2009; Mekonnen and Worku, 2011; Palamuleni, 2010), found that postpartum infecundability had a dominant inhibiting effect on fertility. In comparison to rural, poor, and less educated women, high-income earning women who were more educated and lived in urban areas were less affected by postpartum infecundability. Probably due to the intense working schedules common in urban areas which lead in turn to a small period of postpartum amenorrhea, this could be correlated to shorter breastfeeding. The finding is similar to that of Mahjabeen and Khan (Mahjabeen et al., 2011) and Chola and Michelo's analysis of the World Fertility Survey and Demographic and Health Survey (Chola & Michelo, 2016).

According to the findings of a study conducted among the major Nigerian ethnic groups - Igbo, Yoruba, and Hausa (Titilayo et al., 2018) using the original Bongaart's model, marriage was the top fertility-inhibiting variable among the Igbos, owing to delayed marriage prevalent in this region (Odimegwu and Zerai, 1996). This is consistent with our findings, as the region dominated by Igbos, the South-East (Anedo, 2019), experienced similar patterns from 2003 to 2018 – with delayed sexual exposure having the most fertility inhibiting effect. Furthermore, as previously stated, post-partum infecundability was the main fertility inhibiting variable among the Yoruba and Hausa ethnic groups, followed by the marriage index and contraceptive use (affecting only the Yorubas) (Odimegwu and Zerai, 1996). Nonetheless, the fertility-inhibiting variables changed for the Yorubas, the dominant group in Nigeria's South-Western region, in our current study (Anedo, 2019). Contraception use, post-partum infecundability, and sexual exposure all reduced fertility effectively from 2013 to 2018, possibly as a result of increased education and possibly awareness of different contraception methods in this region. Dev et al. (2016) However, the ferility inhibiting variables remained unchanged for Hausas, who dominate the North Central, North East, and North West regions of Nigeria (Anedo, 2019) and have low educational attainment (Dev et al., 2016), as post-partum infecundability is still the most powerful fertility inhibitor. This indicates that locations and ethnic classifications vary the most effective nearest determinants. As a result, attempts to develop uniform policies for fertility reduction and other health-related issues in Nigeria must take into account the country's diverse social and cultural backgrounds.

In the Southern part of Nigeria, sexual exposure was also the second most important factor in reducing fertility. The significant effectiveness of contraception among women with sexual exposure in the area could be ascribed, with about 77% of contraceptives proven to be effective between 2003 and 2018, which coincides with findings from Dev *et al.,* (2016). This implies that family planning methods aimed at sexually exposed women could have a significant impact on fertility reduction. Similar conclusions were reached in studies conducted in Zambia (Chola and Michelo, 2016), Ethiopia (Laelago et al., 2019), and Uganda (Rutaremwa et al., 2015). When compared to 2018 (30%), the proportion of births prevented due to contraception was higher in 2003 (32%). This disparity in fertility inhibition could be explained by a complementary decrease in the proportion of sexually exposed women, which was 70.2 % in 2003 and 68.2 % in 2018.

In our current study, sterility was the third factor influencing fertility reduction. In 2003, it accounted for 19% of declining fertility, and by 2018, it had slightly increased to 20%. There is little data on the impact of the sterility index on fertility in Sub-Saharan Africa (Chola and

Michelo, 2016; Mekonnen and Worku, 2011). According to Farley and Besley (1988), a large portion of infertility in Sub-Saharan Africa is caused by infections (sexually transmitted diseases) that can be treated with antibiotics—pathological sterility (Farley,T.M.M., 1988). According to Johnston and Hill (Johnston and Hill, 1996), primary sterility had only a minor impact on fertility in 21 developing countries, with values ranging from about 0.7 % to 10% inhibiting fertility. Women who were educated, lived in rural areas, worked, and earned a high income were less susceptible to pathological sterility in our study, just like other variables. This could be attributed to improved access to and understanding of medical care.

Contraception reduced fertility by 19 % in 2003 and increased slightly to 20 % in 2018. These findings are consistent with previous research in Uganda (Moses and Kayizzi, 2007) and Zambia (Chola and Michelo, 2016), which found that contraception had some fertility-inhibiting effects. Contrary to this, studies conducted in Bangladesh and Ethiopia found that contraceptive practice played a significant role in fertility change, most likely due to increased awareness and use of various contraceptive methods (Islam et al., 2015; Laelago et al., 2019). Contraceptive use also played a significant role in explaining fertility disparities in the Philippines (Lai and Tey, 2014). According to the findings from Ghana, Namibia, and Ethiopia, a woman's contraceptive behavior is a significant predictor of fertility outcomes (Mekonnen and Worku, 2011; Palamuleni, 2010; Rutaremwa et al., 2015). The increase observed over a 15-year period could be attributed to increased knowledge of contraception practice, particularly in Nigeria's Northern region (Avidime et al., 2010). Contraception contributed more to fertility inhibition in our current study than it did in Zambia, where contraception use accounted for only 3% of fertility inhibition (Chola and Michelo, 2016). This can be attributed to low contraceptive use, with only 30% of women currently using contraception (Population Institute, 2015). Despite the fact that 97 % of women are aware of any modern contraceptive method (Population Institute, 2015). As a result, “awareness” alone is insufficient to reduce high fertility rates.

Changes in the level of education, the wealth quintile and the number of employees, areas and places of residence could have brought changes in the level of awareness among study participants between the regions that in turn influenced the contraception index as indicated in their results. For women with higher education residing in urban areas and belonging to the richest quintile, use of contraception was increased in this study. This is because women in the above category are more likely to retard marriage and use modern contraception practices (UN Population Division 2002). The variation in education and wealth among participants also resulted in changes in the awareness of contraception in Ethiopia (Laelago et al. 2019). These however did not cover the small proportion of the current consumption of contraceptives by the study participants, which was 35.2% in our 2013 study. In Nigeria and other sub Saharan African countries, numerous family planning programmes, which provide additional insights on the high level of fertility in those countries in relation to their levels of contraceptives, were promoted as birth-space programs in the interests of maternal health and infant health (Chimbwete et al. 2005). (United Nations Department of Economic and Social Affairs and Population Division, 2020).

The abortion measurement was possible in the study contrary to most studies in Sub-Saharan Africa with determinants of fertility (Chola and Michelo, 2016; Mekonnen and Worku, 2011; Rutaremwa et al., 2015). The effect of induced abortion was limited in reducing fertility, with only 6% reduction in fertility between 2003 and 2018. This is probably because abortion induced in Nigeria is illegal except if done to save the life of women (Bankole et al., 2015). This contrasts to developed countries where abortion has a more significant fertility-inhibiting effect (Johnston and Hill, 1996). Data analyzes from 21 developing countries show that abortion seemed to have a similar effect on fertility as contraception (Johnston and Hill, 1996). The impact of our study was clearer in women who are highly educated and reside in urban areas. Probably because of increased education and access to certain facilities, they belong to the workforce and live in urban areas. The findings of studies carried out alongside Majumder and Ram in India with Pallikadavath and Stones show that increased educational achievement among women can lead to an increase in demand for abortion. The results were similar. Unlawful status and the provision of induced abortions have had a great impact on Nigerian fertility with the abortion variable. It also has the second highest level of unmet needs (18 %) in South-South proportions among women using every contraceptive method (29 %) (Bankole et al. 2015) and every contemporary approach (18 %) (Bankole et al., 2015). In this way, people in the south can rely more on abortion and less on contraception than women in other regions to achieve the smaller families they want. This is why abortion is highly inhibitory in this region.

The FEPI and NCIFP latest index suggests that the program work only slightly increased. The decline in FEPI rates in 2009 can be attributed to poor records of actual access for most of the population to contraceptive methods (Smith and Ross, 2011). In 2004, multiple contraceptive methods were available in most of the African countries, although the policy items improved (Ross et al., 2007). But the figures improved by 2014 (see Supplementary Information). The policy part improves the most, three out of four components have a high scoring (Avenir Health, 2017a). These figures simply imply Nigeria's greatest effort in establishing mechanisms for monitoring the availability of voluntary, non-discriminatory family planning information and services at national, sub-national and facility levels. Ensure that all interested populations have equity services (Avenir Health, 2017a).

In general, although significant improvements have been made on family planning over the years, the FPEs and the recent NCIP figures remain very small in comparisons with other Sub-Saharan African (SSA) countries (Smith and Ross, 2011). For example, Liberia and Eritrea were slightly higher than Nigeria within the SSA (2009), respectively 35% and 38%. (Smith and Ross, 2011). Countries like Zimbabwe and Mauritius had 60% and 61% respectively (Smith and Ross, 2011). In addition, the scores may be particularly high as contraceptives are supplemented with maternal services for most women to reduce high rates of abortion (Westoff, 2000, 2005; Westoff et al., 1998). The implementation of these strategies can help the planning efforts of Nigeria's family. However, much more effort is needed to improve Nigeria's FP environment and program environment significantly (Avenir Health, 2017a).

Our findings have shown that the average birth period was constant from 2003 to 2018 at less than 2 years (> 34 months). This is similar to the recommended 3- to 5 years interval in 55

subSaharan Africans from a 2002 population report showing that 57% of women with children's ages practiced birth interval duration less than three years (Setty-Venugopal & Upadhyay, 2002) as well as in studies in African countries. (Fitaw et al., 2003; Negussie, 2000, Orji et al., 2004), and (Rafalimanana and Westoff, 2001; Setty-Venugopal and Upadhyay, 2002; Yohannes et al., 2011). Several factors may have been attributable to a reduction in birth interval, ranging from poor education and a residency as untrained women in rural regions, who have a higher probability of spatial birth than those of older women (Ramara Rao et al., 2006; Setty-Venugopal and Upadhyay, 2002) (RamaRao et al. 2006; Setty-Vehey, 2006; Setty-Rama et al). (Central Statistics Agency & ORC Macro, 2006; Setty-Venugopal and Upadhyay, 2002). While the %age for women under the age of 18 has decreased steadily in the last few years, compared to the developed countries it is still high (United Nations, 2017).

5. CONCLUSION

From our study, it was discovered that among the four proximate determinants of fertility, postpartum infecundability played an important role in influencing fertility. It had the highest fertility inhibiting effect accounting for about 34% fertility reduction. The index of sexual exposure in 2003, 2008 and 2013 played an important role in inhibiting fertility. Contraception use had a higher impact among women with higher education and wealth quintile.

Therefore, the Federal Government of Nigeria and developing partners need to design effective strategies to increase contraceptive use across the country. State-specific policies needs to be developed to address fertility levels across Nigeria. Increasing access to family planning information, services, and methods is essential. Providing high quality family planning services, commodities to support those services, and communication and messaging around family planning all require financial resources. It is critical that enough funds are provided to support these efforts.

These approaches ought to be specific to the different geopolitical zones since There are varying behavioural and proximate determinants unique to these regions. The table below shows top three recommended strategies for each zone based on findings from our study.

Table 7: Top three recommended strategies for fertility reduction in Nigeria's geopolitical zones

Geographical Region	First Suggested Strategy	Second Suggested Strategy	Third Suggested Strategy
North-Central	Heightened awareness and sponsorship on the use of Contraception	Advocacy for delayed sexual exposure through eradication of child marriage prevalent in this region	Enhanced education on the importance of breastfeeding as a family planning method especially among women in rural regions
North-East	Heightened awareness and sponsorship on the use of Contraception	Advocacy for delayed sexual exposure through eradication of child marriage prevalent in this region	Enhanced education on the importance of breastfeeding as a family planning method especially among women in rural regions

North-West	Heightened awareness and sponsorship on the use of Contraception	Advocacy for delayed sexual exposure through eradication of child marriage prevalent in this region	Enhanced education on the importance of breastfeeding as a family planning method especially among women in rural regions
South-East	Enhanced education and promotion of the importance of breastfeeding as a family planning method especially among high income, educated women residing in urban regions.	Continued sponsorship and promotion Contraception use	Promotion of delayed Sexual exposure
South-South	Enhanced education and promotion of the importance of breastfeeding as a family planning method especially among high income, educated women residing in urban regions.	Promotion of delayed Sexual exposure	Continued sponsorship and promotion of the use of contraception
South-West	Enhanced education and promotion of the importance of breastfeeding as a family planning method especially among high income, educated women residing in urban regions.	Promotion of delayed Sexual exposure	Continued sponsorship and promotion of the use of contraception

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