Fertility transition in selected sub-Saharan African countries: the role of family planning programs [version 1; peer review: 1 approved, 1 approved with reservations]

Vincent Otieno, Alfred Agwanda, Anne Khasakhala
Population Studies and Research Institute (PSRI), University of Nairobi, Nairobi, Nairobi, 00100, Kenya

Abstract
Background: Change in fertility rate across societies is a complex process that involves changes in the demand for children, the diffusion of new attitudes about family planning and greater accessibility to contraception provided by family planning programs. Among the neo-Malthusian adherents, it is believed that rapid population growth strain countries’ capacity and performance. Fertility has, however, decelerated in most countries in the recent past. Scholars have concentrated on wide range of factors associated with fertility majorly at the national scale. However, considerably less attention has been paid to the fertility preference - a pathway through which various variables act on fertility. The Sub-Saharan African countries’ disparities amid almost similarities in policies is a cause of concern to demographers.

Methods: Using Bongaarts reformulation of Easterlin and Crimmins conceptual scheme of 1985 on Demographic and Health Survey Data (DHS) data collected overtime across countries, the understanding of the current transition in general would help to reassess and provide explanations to the observed latest fertility dynamics at play. This study therefore is an attempt to explain the current fertility transition through women’s fertility preference.

Results: Results reveal that indeed fertility transition is diverse across countries though generally on a decline course in most of the sub-Saharan countries. The huge disparities in fertility preferences among women of reproductive age and its non-significant change in the implementation indices overtime points at the levels of unmet need to contraception underneath as well as the proportion of demand to family planning commodities satisfied by programs in a bid to allow women implement their fertility desires.

Conclusions: It is therefore plausible to conclude that the improvement of the availability and the uptake of quality birth control technologies is one of the most feasible means through which countries can fast track their fertility transitions.

Keywords
Fertility, Preference Implementation index, family planning, Transition, Sub-Saharan Africa
Introduction
Change in fertility rate across societies is a complex process that involves changes in the demand for children, the diffusion of new attitudes about family planning and greater accessibility to contraception provided by family planning programs. Debates about this transition in Sub-Saharan Africa have almost reached a consensus about its uniqueness since they began in the mid-1990s. The trajectory of African fertility transitions occurred earlier than anticipated if Africa had followed the non-African relationship between fertility and development. However, the pace of decline in fertility rate at the time of onset of the transition in this rate was slower than the comparable pace at the onsets of non-African transitions. The key features of African fertility regimes indicate that at a given level of development, Africa’s fertility is higher, contraceptive use is lower, and desired family size is higher than in non-African less-developed countries.

This raises two fundamentally interrelated concepts observed in a number of developing countries, namely: the extent to which changes in fertility levels are due to changes in fertility preference and the extent to which the observed fertility changes result from the ability of women to implement these fertility desires. In this study we seek to add to our understanding of the fertility transition by examining how countries differ in their patterns of reproductive behavior. We specifically examine trends in the fertility desires and the extent at which the ability to implement fertility desires contributes to the prevailing fertility change.

Methods
Analytical model
Using all the trend data from Measure DHS gathered between 1986 and 2016 across sub-Saharan African countries (listed in Table 1), we apply a reformulation of a conceptual scheme in which the variable ‘fertility’ is measured by the total fertility rate (Ft), a function of the supply of births (natural fertility (Fn)), the demand for births (wanted fertility (Fw)) and the degree of fertility preference implementation index (Ip). The latter in turn is dependent on cost of fertility regulation and cost of unwanted childbearing. The degree of Ip is the net result of a decision-making process in which couples weigh the cost of fertility regulation and the cost of unwanted pregnancy. Figure 1 shows the diagrammatic presentation.

Relationship between variables
According to Bongaarts (1993):

\[ F_n = F_w / C \]  \hspace{1cm} (1)

C is an index ranging from 0 to 1 measuring the proportional reduction in Fn attributed to deliberate birth control mechanisms. Birth control not only confined to contraception also encompass induced abortion practices though always ignored in studies. Fn data is always available and hence the only additional task required is to compute Fn in (i) with an estimate of

C. Bongaarts further provided a procedure for deducing C, with an approach though the limitation was the unavailability of data. Hence:

\[ C = 1 - 1.02 \times U \]  \hspace{1cm} (2)

Where U is the fraction of women in marriage practicing all forms of birth regulation except during the post-partum infecundity period. The error associated with this is negligible. By substituting C in Equation 1 above yields the anticipated approximation of natural total fertility.

Fw computation: According to Bongaarts, the favoured approach is dependent on the equation below:

\[ F_w = F^w + 1.09 - W_m(40 – 49) \]  \hspace{1cm} (3)

Where Fw is the proportion of women who want more children, equaling the resulting total fertility after deleting all births to women who want no more children at the time of the survey and Wm (40–49) is the proportion of women in union aged from 40 to 49 who want no more births.

These two equations helped normalize the biases in order to compute the respective Fw and Ft trends across the regions. With most of the erratic curves expected, a normalization process using the natural logarithms of the equation was applied to give meaning to the various trend curves.

Ip is derived from a synthesis of past studies. It begins from the fact that all social and economic factors of fertility operate through a unified pack of proximate factors to exert an impact on fertility. Easterlin’s economic approach is a model of behavioural and biological factors affecting fertility in developing countries. The model consists of three central concepts: demand for children; the potential supply of children, and the momentary and psychic costs of contraception. According to the model, women whose potential supply of births exceeds demand would consider contraception, taking into consideration the costs involved while choosing suitable family planning methods.

The model is simple and attractive; however, it cannot address dynamic issues and has not succeeded in quantifying these factors in acceptable manner. Emerging from the model is the fact that fertility (measured using Fw) is a function of three determinants namely: supply of births (Fw), demand for births (Fw) and the degree of Ip (Figure 1).

Supply of births (Fw) is measured as natural total fertility. Fw infers the rate of birthing likely to prevail minus the premeditated attempts by spouses to limit their number of children. Demand for births (Fw) is the wanted total fertility defined as the rate of prevailing childbearing after eliminating all unwanted births. Under normal circumstances, it is simply calculated as Fw while eliminating the unwanted births from the numerator. Unwanted births are births occurring after an achievement of the ideal family size. Any births that are mistimed though
| Country            | DHS Survey year | Total fertility rate | Total wanted fertility rate | Natural fertility (fertility rate in absence of any contraception) | Index of preference implementation |
|-------------------|----------------|----------------------|-----------------------------|------------------------------------------------------------------|-----------------------------------|
| Angola            | 2015–16 DHS    | 6.2                  | 4.99                        | 7.21                                                             | 0.45                              |
| Benin             | 2011–12 DHS    | 4.9                  | 4.4                         | 5.64                                                             | 0.6                               |
| Benin             | 2006 DHS       | 5.7                  | 4.89                        | 6.89                                                             | 0.59                              |
| Benin             | 2001 DHS       | 5.6                  | 4.89                        | 6.91                                                             | 0.65                              |
| Benin             | 1996 DHS       | 6.0                  | 5.28                        | 7.21                                                             | 0.63                              |
| Burkina Faso      | 2010 DHS       | 6.0                  | 5.24                        | 7.19                                                             | 0.61                              |
| Burkina Faso      | 2003 DHS       | 5.9                  | 5.21                        | 6.87                                                             | 0.58                              |
| Burkina Faso      | 1998–99 DHS    | 6.4                  | 5.71                        | 7.28                                                             | 0.56                              |
| Burkina Faso      | 1993 DHS       | 6.5                  | 5.8                         | 8.71                                                             | 0.76                              |
| Burundi           | 2010 DHS       | 6.4                  | 5.03                        | 8.24                                                             | 0.57                              |
| Burundi           | 1987 DHS       | 6.9                  | 5.7                         | 7.57                                                             | 0.36                              |
| Cameroon          | 2011 DHS       | 5.1                  | 4.55                        | 6.7                                                              | 0.75                              |
| Cameroon          | 2004 DHS       | 5.0                  | 4.72                        | 6.8                                                              | 0.86                              |
| Cameroon          | 1998 DHS       | 4.8                  | 4.65                        | 5.98                                                             | 0.89                              |
| Cameroon          | 1991 DHS       | 5.8                  | 5.6                         | 6.94                                                             | 0.85                              |
| Chad              | 2014–15 DHS    | 6.4                  | 6.09                        | 6.8                                                              | 0.56                              |
| Chad              | 2004 DHS       | 6.3                  | 6.22                        | 7.1                                                              | 0.91                              |
| Chad              | 1996–97 DHS    | 6.4                  | 6.21                        | 6.68                                                             | 0.6                               |
| Congo             | 2011–12 DHS    | 5.1                  | 4.93                        | 9.37                                                             | 0.96                              |
| Congo             | 2005 DHS       | 4.8                  | 4.67                        | 8.76                                                             | 0.97                              |
| Congo Democratic Republic | 2013–14 DHS | 6.6                  | 5.63                        | 8.33                                                             | 0.64                              |
| Congo Democratic Republic | 2007 DHS | 6.3                  | 5.64                        | 7.98                                                             | 0.72                              |
| Cote d’Ivoire     | 2011–12 DHS    | 5.0                  | 4.75                        | 6.14                                                             | 0.82                              |
| Cote d’Ivoire     | 1998–99 DHS    | 5.2                  | 4.87                        | 6.14                                                             | 0.74                              |
| Cote d’Ivoire     | 1994 DHS       | 5.3                  | 4.9                         | 6.0                                                              | 0.63                              |
| Ethiopia          | 2016 DHS       | 4.6                  | 3.88                        | 7.26                                                             | 0.79                              |
| Ethiopia          | 2011 DHS       | 4.8                  | 3.97                        | 6.78                                                             | 0.7                               |
| Ethiopia          | 2005 DHS       | 5.4                  | 4.05                        | 6.35                                                             | 0.41                              |
| Ethiopia          | 2000 DHS       | 5.5                  | 4.56                        | 6.0                                                              | 0.34                              |
| Ghana             | 2014 DHS       | 4.2                  | 3.65                        | 5.77                                                             | 0.74                              |
| Ghana             | 2008 DHS       | 4.0                  | 3.57                        | 5.26                                                             | 0.75                              |
| Ghana             | 2003 DHS       | 4.4                  | 3.8                         | 5.92                                                             | 0.72                              |
| Ghana             | 1998 DHS       | 4.4                  | 3.83                        | 5.67                                                             | 0.69                              |
| Ghana             | 1993 DHS       | 5.2                  | 4.3                         | 6.56                                                             | 0.6                               |
| Ghana             | 1988 DHS       | 6.4                  | 5.36                        | 7.37                                                             | 0.48                              |
| Guinea            | 2012 DHS       | 5.1                  | 4.84                        | 5.41                                                             | 0.55                              |
| Guinea            | 2005 DHS       | 5.7                  | 5.14                        | 6.28                                                             | 0.51                              |
| Guinea            | 1999 DHS       | 5.5                  | 5.06                        | 5.87                                                             | 0.46                              |
| Kenya             | 2014 DHS       | 3.9                  | 3.08                        | 9.55                                                             | 0.87                              |
| Kenya             | 2008–09 DHS    | 4.6                  | 3.24                        | 8.58                                                             | 0.75                              |
| Country    | DHS Survey year | Total fertility rate | Total wanted fertility rate | Natural fertility (fertility rate in absence of any contraception) | Index of preference implementation |
|------------|-----------------|----------------------|-----------------------------|---------------------------------------------------------------|-----------------------------------|
| Kenya      | 2003 DHS        | 4.9                  | 3.55                        | 8.18                                                          | 0.71                              |
| Kenya      | 1998 DHS        | 4.7                  | 3.29                        | 7.8                                                           | 0.69                              |
| Kenya      | 1993 DHS        | 5.4                  | 3.62                        | 8.1                                                           | 0.6                               |
| Kenya      | 1989 DHS        | 6.7                  | 4.13                        | 9.23                                                          | 0.5                               |
| Lesotho    | 2014 DHS        | 3.3                  | 2.63                        | 8.55                                                          | 0.89                              |
| Lesotho    | 2009 DHS        | 3.3                  | 2.61                        | 6.34                                                          | 0.81                              |
| Lesotho    | 2004 DHS        | 3.5                  | 2.81                        | 5.65                                                          | 0.76                              |
| Liberia    | 2013 DHS        | 4.7                  | 4.19                        | 5.92                                                          | 0.71                              |
| Liberia    | 2007 DHS        | 5.2                  | 4.44                        | 5.88                                                          | 0.47                              |
| Liberia    | 1986 DHS        | 6.7                  | 6.04                        | 7.17                                                          | 0.42                              |
| Madagascar | 2008–09 DHS     | 4.8                  | 3.75                        | 8.09                                                          | 0.76                              |
| Madagascar | 2003–04 DHS     | 5.2                  | 4                           | 7.19                                                          | 0.62                              |
| Madagascar | 1997 DHS        | 6                   | 4.53                        | 7.48                                                          | 0.5                               |
| Madagascar | 1992 DHS        | 6.1                  | 4.46                        | 7.35                                                          | 0.43                              |
| Malawi     | 2015–16 DHS     | 4.4                  | 3.32                        | 11.11                                                         | 0.86                              |
| Malawi     | 2010 DHS        | 5.7                  | 3.97                        | 10.76                                                         | 0.75                              |
| Malawi     | 2004 DHS        | 6                   | 4.4                         | 8.98                                                          | 0.65                              |
| Malawi     | 2000 DHS        | 6.3                  | 4.47                        | 9.16                                                          | 0.61                              |
| Malawi     | 1992 DHS        | 6.7                  | 5.61                        | 7.22                                                          | 0.48                              |
| Mali       | 2012–13 DHS     | 6.1                  | 5.42                        | 6.82                                                          | 0.51                              |
| Mali       | 2006 DHS        | 6.6                  | 5.85                        | 7.2                                                           | 0.44                              |
| Mali       | 2001 DHS        | 6.8                  | 5.87                        | 7.41                                                          | 0.4                               |
| Mali       | 1995–96 DHS     | 6.7                  | 5.96                        | 7.19                                                          | 0.4                               |
| Mali       | 1987 DHS        | 7.1                  | 6.35                        | 7.46                                                          | 0.32                              |
| Mozambique | 2011 DHS        | 5.9                  | 4.95                        | 6.69                                                          | 0.46                              |
| Mozambique | 2003 DHS        | 5.5                  | 4.91                        | 7.43                                                          | 0.77                              |
| Mozambique | 1997 DHS        | 5.2                  | 5.03                        | 5.52                                                          | 0.65                              |
| Namibia    | 2013 DHS        | 3.6                  | 2.91                        | 8.42                                                          | 0.87                              |
| Namibia    | 2006–07 DHS     | 3.6                  | 2.68                        | 8.22                                                          | 0.83                              |
| Namibia    | 2000 DHS        | 4.2                  | 2.93                        | 7.58                                                          | 0.73                              |
| Namibia    | 1992 DHS        | 5.4                  | 4.43                        | 7.66                                                          | 0.7                               |
| Niger      | 2012 DHS        | 7.6                  | 7.19                        | 8.86                                                          | 0.75                              |
| Niger      | 2006 DHS        | 7                   | 6.72                        | 7.9                                                           | 0.76                              |
| Niger      | 1998 DHS        | 7.2                  | 6.83                        | 7.86                                                          | 0.64                              |
| Niger      | 1992 DHS        | 7                   | 6.71                        | 7.33                                                          | 0.53                              |
| Nigeria    | 2013 DHS        | 5.5                  | 5.16                        | 6.5                                                           | 0.75                              |
| Nigeria    | 2008 DHS        | 5.7                  | 5.24                        | 6.7                                                           | 0.69                              |
| Nigeria    | 2003 DHS        | 5.7                  | 5.31                        | 6.54                                                          | 0.68                              |
| Nigeria    | 1990 DHS        | 6                   | 5.65                        | 6.39                                                          | 0.53                              |
| Rwanda     | 2014–15 DHS     | 4.2                  | 3.26                        | 9.18                                                          | 0.84                              |
| Rwanda     | 2010 DHS        | 4.6                  | 3.26                        | 9.71                                                          | 0.79                              |
| Rwanda     | 2007–08 DHS     | 5.5                  | 3.78                        | 8.75                                                          | 0.65                              |
| Country     | DHS Survey year | Total fertility rate | Total wanted fertility rate | Natural fertility (fertility rate in absence of any contraception) | Index of preference implementation |
|-------------|-----------------|----------------------|-----------------------------|------------------------------------------------------------------|----------------------------------|
| Rwanda      | 2005 DHS        | 6.1                  | 4.35                        | 7.42                                                            | 0.43                             |
| Rwanda      | 2000 DHS        | 5.8                  | 4.64                        | 6.7                                                             | 0.44                             |
| Rwanda      | 1992 DHS        | 6.2                  | 4.71                        | 7.91                                                            | 0.53                             |
| Senegal     | 2016 DHS        | 4.7                  | 4.59                        | 6.32                                                            | 0.93                             |
| Senegal     | 2015 DHS        | 4.9                  | 4.76                        | 6.43                                                            | 0.91                             |
| Senegal     | 2014 DHS        | 5.0                  | 4.77                        | 6.46                                                            | 0.87                             |
| Senegal     | 2012–13 DHS     | 5.3                  | 4.92                        | 6.48                                                            | 0.76                             |
| Senegal     | 2010–11 DHS     | 5.0                  | 4.7                          | 5.77                                                            | 0.72                             |
| Senegal     | 2005 DHS        | 5.3                  | 4.92                        | 6.03                                                            | 0.66                             |
| Senegal     | 1997 DHS        | 5.7                  | 5.09                        | 6.56                                                            | 0.59                             |
| Senegal     | 1992–93 DHS     | 6.0                  | 5.4                         | 6.5                                                             | 0.46                             |
| Senegal     | 1986 DHS        | 6.4                  | 5.74                        | 7.23                                                            | 0.56                             |
| Sierra Leone| 2013 DHS        | 4.9                  | 4.45                        | 5.9                                                             | 0.69                             |
| Sierra Leone| 2008 DHS        | 5.1                  | 4.4                         | 5.57                                                            | 0.4                              |
| Tanzania    | 2015–16 DHS     | 5.2                  | 4.51                        | 8.55                                                            | 0.83                             |
| Tanzania    | 2010 DHS        | 5.4                  | 4.59                        | 8.32                                                            | 0.78                             |
| Tanzania    | 2004–05 DHS     | 5.7                  | 4.78                        | 7.8                                                             | 0.7                              |
| Tanzania    | 1999 DHS        | 5.6                  | 4.76                        | 7.56                                                            | 0.7                              |
| Tanzania    | 1996 DHS        | 5.8                  | 4.82                        | 7.14                                                            | 0.58                             |
| Tanzania    | 1991–92 DHS     | 6.2                  | 5.4                         | 6.94                                                            | 0.48                             |
| Togo        | 2013–14 DHS     | 4.8                  | 4.15                        | 6.02                                                            | 0.65                             |
| Togo        | 1998 DHS        | 5.2                  | 4.53                        | 6.84                                                            | 0.71                             |
| Togo        | 1988 DHS        | 6.4                  | 5.44                        | 9.78                                                            | 0.78                             |
| Uganda      | 2011 DHS        | 6.2                  | 4.41                        | 8.93                                                            | 0.6                              |
| Uganda      | 2006 DHS        | 6.7                  | 4.72                        | 8.84                                                            | 0.52                             |
| Uganda      | 2000–01 DHS     | 6.9                  | 4.97                        | 8.99                                                            | 0.52                             |
| Uganda      | 1995 DHS        | 6.9                  | 5.32                        | 8.13                                                            | 0.44                             |
| Uganda      | 1988–89 DHS     | 7.4                  | 6.17                        | 7.79                                                            | 0.24                             |
| Zambia      | 2013–14 DHS     | 5.3                  | 4.23                        | 10.6                                                            | 0.83                             |
| Zambia      | 2007 DHS        | 6.2                  | 4.75                        | 10.62                                                           | 0.75                             |
| Zambia      | 2001–02 DHS     | 5.9                  | 4.61                        | 9.06                                                            | 0.71                             |
| Zambia      | 1996 DHS        | 6.1                  | 5.06                        | 8.29                                                            | 0.68                             |
| Zambia      | 1992 DHS        | 6.5                  | 5.53                        | 7.69                                                            | 0.55                             |
| Zimbabwe    | 2015 DHS        | 4.0                  | 3.43                        | 12.55                                                           | 0.94                             |
| Zimbabwe    | 2010–11 DHS     | 4.1                  | 3.49                        | 10.17                                                           | 0.91                             |
| Zimbabwe    | 2005–06 DHS     | 3.8                  | 3.22                        | 9.85                                                            | 0.91                             |
| Zimbabwe    | 1999 DHS        | 4.0                  | 3.43                        | 8.8                                                             | 0.89                             |
| Zimbabwe    | 1994 DHS        | 4.3                  | 3.67                        | 8.44                                                            | 0.87                             |
| Zimbabwe    | 1988 DHS        | 5.4                  | 4.38                        | 9.64                                                            | 0.81                             |
occurring before the achievement of the desired family size are considered wanted births as well.

The degree of \( I_p \) is an index from zero value to unity. Its level of implementation implies the net result of decision-making process. This is the state in which a spouse ponders the cost of fertility regulation as they consider costs of bearing an unwanted child to its end. In general, the index has an inverse variation to the cost of fertility regulation as well as a reverse correlation to the unwanted births. If couples fully implement their fertility preference, the index is equal to unity. This signifies that no unwanted births occur as actual fertility corresponds to \( w \ F_w \). Conversely, if the index is equal to zero, the observed fertility equals \( F_n \), that is, fertility in the absence of any deliberate fertility control assuming women remain sexually active over their reproductive cycles. The value of the index at play stipulates the position where actual fertility falls as dictated by the range set between wanted and \( F_w \) parameter levels.

\( F_0 \) gives the estimate of the number of children a woman would have by the end of childbearing if she were to pass through her reproductive cycle at the customary age specific birth rates. The model shows that the operation of these variables determines the level of fertility in a community or households. In this variant of the original Easterlin and Crimmins (1985) model, infant and child mortality dynamics affects the desired fertility rather than \( F_n \). Women are deemed to possess precise desired fertility size translated and actualized into numbers through subsequent births after considering past child losses and risks related to future child deaths as well.

According to this variant, as development occurs, the trend in prevailing fertility transforms to become a function of the equilibrium between the \( F_w \), \( F_u \) and the degree of fertility \( I_p \). \( F_u \) is expected to decline over time, as a result of the changes associated with the costs and benefits of child bearing, as well as reductions in the infant-child mortality. \( I_p \) rises as fertility regulation costs decline; with the benefit of fertility regulation focusing on the elimination of any unwanted births. According to \( I_p \), the relationship between these variables under discussions and fertility can be expressed in statistical form as follows:

\[
F_0 = F_w + F_u \quad (4)
\]

Where \( F_u \) is the unwanted fertility (which can simply be expressed as \( F_0 - F_w \)).

\[
F_u = (F_n - F_u) \times (1 - I_p) \quad (5)
\]

Where \( I_p \) has a range of 0 to 1. With full \( I_p \), \( I_p = 1 \) (which implies that \( F_w = 0 \) and \( F_u = F_n \)) and \( I_p = 0 \) with no prefer \( I_p \) (This implies a substantial level of unwanted childbearing and \( F_u = F_n \)). Noted here is that as defined by Bongaarts, \( F_0 \) here is not the same as in total fecundity as in the Bongaarts proximate determinants but taken to mean fertility level achieved in absence of contraception.

\( F_0 \) is a function of the difference between supply and demand, and the degree of \( I_p \).

Substitution of Equation 5 in Equation 6 yields:

\[
F = F_w \times I_p + F_u \times (1 - I_p) \quad (6)
\]

Noting that \( F_n \) is given by:

\[
F_n = F_0 / C
\]

Where \( C \) implies an index ranging from 0 to 1 measuring the reduction in proportional of \( F_n \) attributable to deliberate birth control is estimated as:

\[
C = 1 - 1.02 \times U
\]
Where U represents the proportion of married women who were practicing contraception at the time of survey. It is measured as the number of married women using contraceptive method to the total number of married women. The values for U and C can be used to estimate F

Rearranging Equation 6 gives:

Equation 7 can now be used to estimate the degree of I

Equation 7 can now be used to estimate the degree of I

The analysis consists of two stages. First, we computed the degree of I

The analysis consists of two stages. First, we computed the degree of I

Decomposition of fertility trends

According to Bongaarts (1993), the core objective of the demand framework lies in the identification of the causes of fertility decline in a population, with proceeding comparative analysis providing worthwhile insights yet not achieving its sole objective. Turning to the issue at hand, the decomposition of the variations in fertility and to abridge the methodological exposition, trends therefore should inform the basis of focus between two points in time, i.e. T and T, running up to the determinants. The derivation of the decomposition equation also warrants the introduction of the variables listed in Table 2.

| Variable                | Observation point |
|-------------------------|-------------------|
| Time Periods            | T, T           |
| Total Fertility         | F, F           |
| Natural Fertility       | F, F           |
| Wanted Fertility        | F, F           |
| Index of Implementation | I, I           |

Source: Bongaarts (1993)

The decline in fertility between the two periods is F - F, conveyed by substitution as

The above equation therefore can be written as below

In Equation 8: ΔF, ΔF, ΔF, ΔF and ΔF are the change within F, F, F, F

In Equation 9: F, F and F are the mean values of correspondingly, F, F and F. For example, the mean of the degree of implementation index (I) is: - [0.5(I + I)]

I implies the average of the Degree of Fertility Implementation Index (I). The influence of change in wanted (ΔF) as well as the natural (ΔF) fertility to prevailing fertility change hinge on the average extent or degree of implementation. Consequently, the outcome of fertility from every shift registered on the degree of fertility implementation index is determined by the corresponding mean change between F and F (I - I). This function requires two successive points in the estimates of the parameter measurers i.e. F, F natural and F including the implementation index as well within the population under consideration. It is this function that is used to determine the extent to which implementation of fertility desires contributes to fertility transition.

Results

Decomposition of fertility change and the contribution of F

As Table 1 shows the trend change in fertility parameters measurers, Table 3 further shows the decomposition of fertility changes among countries with two or more surveys. Results reveal there are indeed substantial variations between countries in terms of fertility preference parameter measurers as well as the implementation indices by countries. These results clearly indicate the important role played by the changes in I, F, F and F. Converse to the expected, eight countries actually increased their F over the period 1986–2016. In six out of the eight countries where fertility increased, there was a decline in degree of I. The largest decline in fertility rate occurred in Rwanda, Malawi, Kenya and Ethiopia. The four countries subsequently had the greatest contribution of the degree of I to fertility decline. On the same note the greatest contribution of F decline to fertility change occurred in Malawi, Rwanda and Kenya.

In absolute values, Rwanda, Malawi and Kenya experienced the highest fertility changes as well, while Niger, Mozambique and DRC experienced an increase in fertility rate within
Table 3. Contribution of wanted fertility rate and preference implementation index to fertility change in selected Sub-Saharan African countries.

| Country     | Surveys Year | Change in $F_o$ | Change in $F_o$ | Absolute Contribution to $F_o$ Change | Percent Contribution to $F_o$ Change |
|-------------|--------------|-----------------|-----------------|--------------------------------------|---------------------------------------|
|             | Baseline     | Last            | Gap             | $F_w$      | $F_n$ | $I_p$ | $T_w$ | $T_n$ | $I_p$ | $T_w$ | $T_n$ | $I_p$ |
| Rwanda      | 2005         | 2014            | 9               | 1.89       | 0.69  | -0.64 | 1.84  | 37    | -34  | 97    |
| Malawi      | 2004         | 2015            | 11              | 1.59       | 0.82  | -0.25 | 2.27  | 64    | -61  | 125   |
| Kenya       | 2003         | 2014            | 11              | 1.00       | 0.45  | -0.29 | 0.84  | 36    | -30  | 88    |
| Ethiopia    | 2005         | 2016            | 11              | 0.82       | 0.10  | -0.36 | 1.08  | 45    | -29  | 84    |
| Benin       | 2001         | 2011            | 10              | 0.70       | 0.31  | 0.48  | -0.08 | 44    | 68   | -12   |
| Uganda      | 2000         | 2011            | 11              | 0.68       | 0.31  | 0.30  | 0.34  | 46    | 4    | 50    |
| Guinea      | 2005         | 2012            | 7               | 0.60       | 0.16  | 0.41  | 0.03  | 0.34  | 46   | 4     |
| Senegal     | 2005         | 2016            | 11              | 0.59       | 0.26  | -0.06 | 0.38  | 45    | -10  | 65    |
| Zambia      | 2001         | 2013            | 12              | 0.59       | 0.29  | -0.35 | 0.65  | 50    | -60  | 111   |
| Namibia     | 2000         | 2013            | 13              | 0.56       | 0.02  | -0.17 | 0.71  | 3     | -30  | 127   |
| Lesotho     | 2004         | 2014            | 10              | 0.51       | 0.15  | -0.02 | 0.38  | 29    | -3   | 74    |
| Liberia     | 2007         | 2013            | 6               | 0.51       | 0.15  | -0.02 | 0.38  | 29    | -3   | 74    |
| Mali        | 2006         | 2012            | 6               | 0.50       | 0.20  | 0.2   | 0.1   | 41    | 40   | 19    |
| Tanzania    | 2004         | 2015            | 11              | 0.49       | 0.21  | -0.18 | 0.46  | 42    | -36  | 94    |
| Madagascar  | 2003         | 2008            | 5               | 0.42       | 0.17  | -0.28 | 0.53  | 41    | -66  | 125   |
| Nigeria     | 2003         | 2013            | 10              | 0.42       | 0.11  | 0.01  | 0.09  | 37    | -34  | 97    |
| Cote d’Ivoire | 1998      | 2011            | 13              | 0.21       | 0.09  | 0     | 0.11  | 47    | 0    | 53    |
| Sierra Leone| 2008         | 2013            | 5               | 0.20       | -0.03 | -0.15 | 0.38  | -14   | -74  | 188   |
| Ghana       | 2003         | 2014            | 11              | 0.20       | 0.11  | 0.04  | 0.04  | 57    | 21   | 22    |
| Cameroon    | 2004         | 2011            | 7               | 0.19       | 0.14  | -0.02 | -0.23 | -179  | 26   | 305   |
| Burkina Faso| 2003         | 2010            | 7               | -0.08      | -0.02 | -0.13 | 0.05  | 19    | 139  | -58   |
| Chad        | 2004         | 2014            | 10              | -0.09      | -0.10 | 0.08  | -0.28 | -93   | -77  | 270   |
| Zimbabwe    | 2005         | 2015            | 10              | -0.10      | -0.19 | -0.02 | 0.24  | 121   | 126  | -147  |
| Congo       | 2005         | 2011            | 6               | -0.31      | -0.25 | -0.02 | -0.04 | 80    | 7    | 14    |
| Congo DR    | 2007         | 2013            | 6               | -0.31      | -0.01 | -0.11 | -0.2  | -2    | 37   | 66    |
| Mozambique  | 2003         | 2011            | 8               | -0.40      | -0.03 | -0.29 | -0.66 | 6     | -71  | 165   |
| Niger       | 2006         | 2012            | 6               | -0.60      | -0.36 | -0.24 | -0.01 | 59    | 39   | 2     |

$F_o$, total fertility rate.

The periods 1986–2016. Looking at the contributions made by each of the fertility parameters, the fertility preference ($F_w$) and the degree of $I_p$ are the reasons for the variations in the changes in fertility. Rwanda registered a 37% decrease in its average wanted fertility desires, with a corresponding degree of $I_p$ of 97% (Table 2). Malawi and Kenya on the same note registered a reduction in $F_w$ of 51% and 54% and corresponding implementation indices of 82% and 84%, respectively.

Figure 2 highlights the graphical correlation between $I_p$ and unmet need for family planning. There is an inverse correlation between $I_p$ and the unmet need for family planning. High unmet need for contraception leads to a low implementation index, since contraception is the sole contributing factor to fertility regulation (also referred to as the extent of $I_p$). This is because the extent of contraceptive availability and subsequent utilization of contraceptives is what defines $I_p$ level. The absence of these essential birth control commodities leads to non-implementation of family planning, thereby failing to restrain $F_n$.

Figure 3 echoes the performance of $I_p$ in facilitating the reduction of fertility by each of the countries within the periods under study. Ethiopia, Rwanda and Sierra Leone are the three
Figure 2. Correlation between implementation index and unmet need for family planning.

Figure 3. Percent change in preference implementation since 2000.
countries where $I_p$ has most contributed to the fertility decline. However, in some countries, the limited or non-implementation of fertility led to the index not facilitating any declines in $F_w$, thereby allowing the natural increase to take its course. These countries were Mozambique, Chad, Cameroun, Democratic Republic of Congo, Togo, Benin, and Congo Brazzaville.

**Discussion and conclusion**

Based on the fertility preference and implementation indicators, fertility transition is indeed on course in a number of countries, going by the trend data for each country. The extent at which this occurs varies across countries, with each country exhibiting varied levels of implementation. The $F_w$ and the degree of $I_p$ are therefore key to the prevailing fertility in each country. Countries where populations desired or $F_w$ are in decline over time are believed to be high in their drive to lower their overall $F_w$. The suppressed desired or $F_w$ correspond to a high index of implementation. Subsequently, exhibit the highest transition changes. The prevailing $F_w$ of a country therefore depends on the interplay between the fertility desires and the degree of $I_p$, which is dependent on the availability of family planning commodities (proportion of demand satisfied). Reduction in fertility hence demands low desired fertility and high index of implementation simultaneously. This implies that those countries with only one high parameter performance (i.e. either suppressed $F_w$ or high implementation index) among the two exhibits only but between moderate to limited reduction in fertility change.

Further, the generally observed decline in the indices of fertility (i.e. $F_w$, $F_p$, $I_p$ and $I_n$) confirms the strength of the family planning program efforts by the various stakeholders in making birth control technologies available (to curb the unmet need thereby satisfying demand), accessible and affordable to their populace as well as improved contraceptive technology. This is due to the fact that only birth control technologies are known to facilitate the implementation of couples’ fertility desires. Looking at the association between $I_p$ and the unmet need for contraception (Figure 2), countries with high unmet need for contraception exhibit low values of $I_p$.

The converse is also true. The unmet need for contraception also reflects the proportion of demand satisfied. High unmet need for contraception is a function of lower total supply of family planning commodities required by all those women in need; implying low proportion of demand satisfied by the birth control commodities under the assumption that women of reproductive age are sexually active. This therefore leads to a surge in births as family planning is reduced owing to lower supplies of commodities than demanded. The unmet need has, however, progressively slowed over the years as births have reduced overtime in the majority of countries within the sub-Saharan Africa; reflected too by the surging implementation index overtime (Table 4). This finding reflects the level of increase in sensitization, advocacy and public education by programs as well as the utilization of birth control technologies. $F_w$ as a key parameter measure for the fertility change, relies heavily on the proportion of demand for contraception that is satisfied$. F_w$ is only achievable through the conscious attempt by spouses to deliberately control the number of births they wish to have, assuming all women are reproductive and sexually active at the same time.

With the population well sensitized to trigger conscious decision making with regards to contraceptive use, this sensitization will subsequently influence the couples to demand for specific number of births within their means as opposed to mere natural child bearing with no control. It is therefore plausible to conclude that the improvement of the availability and the uptake of birth control technologies to a sensitized population is one of the most feasible means through which countries can fast track their fertility transitions. The access should not only take into consideration the quantity but also the quality of contraception available. Unconstrained access to contraception is therefore an important marker, with the index level acting as a proxy measure. The association between $I_p$ and the unmet need to contraception suggests that this index can be used as an indicator for program success efforts. Going by the countries’ performances over time, thereby taking into consideration the constants (such as reproductive age and economic situation) and non-constants (such as health system endowment), one can conclude that the current fertility transition witnessed in Sub-Saharan Africa is only modest, but a work in progress at the same time. Further research is recommended on how best $I_p$ can be used as a measure of family planning program efforts.

**Data availability**

The datasets analyzed during the current study are available in the MEASURE DHS repository, (http://www.measuredhs.com). Access to the dataset requires registration, and is granted to those that wish to use the data for legitimate research purposes. A guide for how to apply for dataset access is available at: https://dhsprogram.com/data/Access-Instructions.cfm. The DHS datasets used in this study are shown in Table 1.

### Table 4. Fertility change contribution.

| Change ($\Delta$) in key measures | Contribution to fertility decline ($\Delta F$) |
|-----------------------------------|---------------------------------------------|
| $\Delta F_w$                       | $\Delta F_w (1- I_p)$                      |
| $\Delta I_p$                       | $\Delta F_p \times I_p$                   |
| Degree of $\Delta I_p$             | $\Delta I_p (\text{Average } F_w - \text{Average } F_p)$ |

Source: Bongaarts (1993). $F_w$: natural fertility; $F_p$: wanted fertility; $I_p$: fertility implementation index.
References

1. Bongaarts J: Development: Slow down population growth. Nature. 2016; 530(7591): 409–12.
   PubMed Abstract | Publisher Full Text

2. Bongaarts J, Casterline J: Fertility Transition: Is sub-Saharan Africa Different? Popul Dev Rev. 2013; 38(Suppl 1): 153–68.
   PubMed Abstract | Publisher Full Text | Free Full Text

3. Agwanda A, Amani H: Population growth, structure and momentum in Tanzania. Economic and Social Research Foundation, 2014.
   Reference Source

4. Ibisomi LD, Odimegwu CO, Otieno AT, et al. editors: Degree of preference implementation and fertility changes in developing countries. THE XXVTH IUSSP CONFERENCE Tours, France, 2005.
   Reference Source

5. Bongaarts J: The supply-demand framework for the determinants of fertility: An alternative implementation. Popul Stud. 1993; 47(3): 437–56.
   Publisher Full Text

6. Easterlin RA, Crimmins EM: The fertility revolution: A supply-demand analysis. University of Chicago Press; 1985; 211–18.
   Reference Source

7. Westoff CF, Ngabo F, Umubyeyi MA, et al.: Rwanda 2010: A dramatic change in reproductive behavior. Calverton, Maryland, USA: ICF International, 2013.
   Reference Source

8. Agwanda A, Khasakhala A, Kimani M: Assessment of family planning services in Kenya: Evidence from the 2004 Kenya Service Provision Assessment survey. Calverton, Maryland, USA: Macro International, 2009.
   Reference Source
Open Peer Review

Current Peer Review Status:  ?  

Version 1

Reviewer Report 24 January 2020

https://doi.org/10.5256/f1000research.22630.r57588

© 2020 Kiarie J. This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

James Kiarie
Department of Reproductive Health and Research, World Health Organization (WHO), Geneva, Switzerland

Abstract Background: “disparities amid almost similarities in policies is a cause of concern to demographers” – not sure what this is in reference to

Abstract Methods:
- ‘Using Bongaarts reformulation of Easterlin and Crimmins conceptual scheme of 1985 on Demographic and Health Survey Data (DHS) data collected overtime across countries’ – Not clear what the next sentences are justifying.
- ‘The understanding of the current transition in general would help to reassess and provide explanations to the observed latest fertility dynamics at play. This study therefore is an attempt to explain the current fertility transition through women’s fertility preference’ – Justification should be moved to background or objectives

Introduction:
- The sentences “African fertility transitions occurred earlier than anticipated if Africa had followed the non-African relationship between fertility and development” and “The key features of African fertility regimes indicate that at a given level of development, Africa’s fertility is higher,” are contradictory.

The authors need to discuss the limitation of the model. Such assumption is that \( F_0 = F_w + F_u \) yet we know there are situations that \( F_0 \) is less than \( F_w \). How will this explain an increasing observation that due to various factors many women do not achieve their desired fertility.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Reproductive health and epidemiology

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 15 January 2020

https://doi.org/10.5256/f1000research.22630.r58569

© 2020 Weis J. This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Julianne Weis
Office of Population and Reproductive Health, USAID (United States Agency for International Development), Arlington, VA, USA

This is a welcome exploration of a key source of debate in the FP/RH world: what is the more important source of fertility transition: population fertility preferences or contraception service delivery? The analysis was sound, but a qualified statistician needs to review the calculations to ensure accuracy.

However, the conclusions are convincing on the importance of service delivery implementation and its relation to fertility transition.

I would welcome more exploration of literature exploring this critical question - currently the article does not touch on other studies or the debates and calculations other authors have conducted. This is a huge gap in the study.

There is also not enough discussion of implications of findings for policy in FP/RH.

The article also needs a thorough copy-edit, especially the abstract, where results are written in a confused, unclear manner.

Is the work clearly and accurately presented and does it cite the current literature?
Partly
Is the study design appropriate and is the work technically sound?  
Yes

Are sufficient details of methods and analysis provided to allow replication by others?  
Yes

If applicable, is the statistical analysis and its interpretation appropriate?  
I cannot comment. A qualified statistician is required.

Are all the source data underlying the results available to ensure full reproducibility?  
Yes

Are the conclusions drawn adequately supported by the results?  
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Family planning, reproductive health, health systems, sub-Saharan Africa, global health, policy

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 20 May 2020

Vincent Otieno, University of Nairobi, Nairobi, Kenya

This is a welcome exploration of a key source of debate in the FP/RH world: what is the more important source of fertility transition: population fertility preferences or contraception service delivery? The analysis was sound, but a qualified statistician needs to review the calculations to ensure accuracy. However, the conclusions are convincing on the importance of service delivery implementation and its relation to fertility transition.

I would welcome more exploration of literature exploring this critical question - currently the article does not touch on other studies or the debates and calculations other authors have conducted. This is a huge gap in the study.

Comment: This is already rectified in the reviewed manuscript and uploaded

There is also not enough discussion of implications of findings for policy in FP/RH.

Comment: I have reworked the discussion of findings section to incorporate FP/RH

The article also needs a thorough copy-edit, especially the abstract, where results are written in a confused, unclear manner

Comment: The abstract has been reworked

• Is the work clearly and accurately presented and does it cite the current literature?Partly

• Comment: All citations updated
| Question                                                                 | Answer |
|-------------------------------------------------------------------------|--------|
| Is the study design appropriate and is the work technically sound?       | Yes    |
| Are sufficient details of methods and analysis provided to allow replication by others? | Yes    |
| If applicable, is the statistical analysis and its interpretation appropriate? | I cannot comment. A qualified statistician is required. |
| Comment: The statistical analysis have been validated by my supervisor Prof Alfred Agwanda of the University of Nairobi - Population Studies and Research Institute (PSRI) |
| Are all the source data underlying the results available to ensure full reproducibility? | Yes    |
| Are the conclusions drawn adequately supported by the results? | Yes    |

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:**
- Family planning
- Reproductive health
- Health systems
- Sub-Saharan Africa
- Global health
- Policy

**Author Response 20 May 2020**

Vincent Otieno, University of Nairobi, Nairobi, Kenya

All reviewer comments rectified

**Competing Interests:** No competing interests were disclosed.

---

The benefits of publishing with F1000Research:

- Your article is published within days, with no editorial bias
- You can publish traditional articles, null/negative results, case reports, data notes and more
- The peer review process is transparent and collaborative
- Your article is indexed in PubMed after passing peer review
- Dedicated customer support at every stage

For pre-submission enquiries, contact research@f1000.com