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Fertility Transition Across Subnational Areas of Sub-Saharan Africa: Where do They Stand and What has Contributed Most?

David A. Sánchez-Páez[1] | Bruno Schoumaker[2]

[1]Department of Economic Theory, Universidad de Valladolid, Valladolid, Spain | [2]Centre for Demographic Research, Université catholique de Louvain, Louvain-la-Neuve, Belgium

Correspondence: David A. Sánchez-Páez (david.sanchezpaez@uva.es)

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ABSTRACT

Stylized models of fertility transition predict that fertility declines first in urban areas and then in rural areas. Although capital cities are assumed to be at the forefront of a country's fertility transition, they have not been widely studied in sub-Saharan Africa. In addition, fertility transition in other urban and rural areas has also been understudied. Using 155 Demographic and Health Surveys, we first calculate fertility rates to determine at which stage each of the three subnational areas in 34 countries is in the fertility transition. We then estimate the fertility-inhibiting effect of the proximate determinants of fertility to analyze what has contributed most to the transition. Our results confirm that capital cities lead fertility transition, as they tend to be one phase further in the transition than other urban areas and two phases further than rural areas. We find that the subnational areas that have made the most rapid progress in the transition are those with a sharp increase in the fertility-inhibiting effect of contraception; however, contraceptive use remains low. Although the inhibiting effect of contraception increases as the fertility transition progresses, the greatest inhibiting effect is that of postpartum infecundability, which is a common feature for virtually all subnational areas, even at the most advanced stages of the transition. In the context of stalled fertility in sub-Saharan Africa, reducing the duration of postpartum infecundability without offsetting it with an increase in contraceptive use leaves open the possibility of further fertility stalls or longer-lasting current stalls.

1 | Introduction

Fertility transition consists of the decline in the total fertility rate (TFR) from high rates to replacement level. Stylized models of fertility transition predict that fertility declines first in urban areas and then in rural areas (Dyson 2011; Shapiro and Tambashe 2002), as urban dwellers have a higher standard of living and better access to education, health care and family planning services (Corker 2017; Lerch 2019). Evidence also shows heterogeneity within urban areas, as large cities, usually the capitals, begin the fertility transition earlier in both developed and less developed countries (Corker 2017; Rodrigo-Comino et al. 2021).

Focusing on the context of less developed countries, the exceptional fertility transition in sub-Saharan Africa (SSA) has been widely discussed in recent decades (Bongaarts and Casterline 2013; Caldwell and Council 1994; Caldwell et al. 1992; Lesthaeghe 2014; Sánchez-Páez and Schoumaker 2022). Fertility transition in SSA began in the early 1980s and by the mid-1990s it was underway in many countries (Garenne and Joseph 2002; Shapiro and Tambashe 2002). However, halts and reversals in fertility decline have been found in several SSA countries since the 2000s (Bongaarts 2008; Schoumaker 2019; Shapiro and Hinde 2017). In most cases, fertility has stalled at rates well above replacement level. At the subnational level, recent analyses suggest that periods of fertility stagnation are widespread in SSA capitals (Schoumaker and Sánchez-Páez 2020). In addition, fertility transition has not yet begun in many rural areas of SSA. Yet, little is known about what has contributed to the slow fertility decline in subnational areas of SSA and whether it is the same determinants that explain fertility variations across areas.

Although capital cities are at the forefront of a country's fertility transition, they have not been widely studied in SSA. In addition, the study of the fertility transition in other urban areas and rural areas in SSA is of great relevance and also understudied, either in countries where urbanization is still low or where it has grown rapidly. On the one hand, if urbanization is still low, the fertility patterns of the largest population subgroup, that is, rural population, greatly affects the country-level total fertility rate and the population growth. On the other hand, recent research has claimed that the rapid increase in urbanization is due to natural growth (Collier 2017; Menashe-Oren and Bocquier 2021), suggesting persistent high fertility rates among urban dwellers. As for urban areas other than capital cities, evidence shows that fertility rates there are higher than in capital cities and lower than in rural areas (Schoumaker and Sánchez-Páez 2020). Disentangling the differences between the three subnational areas may contribute to a better understanding of the fertility transition in SSA.

2 | Phases of the Fertility Transition

Bongaarts (1982) and Bongaarts and Potter (1983) presented a framework to analyze the role of proximate determinants in the fertility transition. They propose four phases of fertility transition, and consider that fertility changes over time can be explained by changes in four proximate determinants of fertility: sexual exposure, contraception, postpartum infecundability, and abortion (Bongaarts 1978, 2015; Bongaarts and Potter 1983). Each of these determinants has an inhibiting effect on fertility: fertility is reduced as a result of lower sexual exposure, greater use of contraception, more frequent abortion, and longer periods of breastfeeding and postpartum abstinence (Bongaarts 1982). The fertility-inhibiting effects of the proximate determinants differ as the fertility transition progresses:

I. TFR over 6.0: Fertility-inhibiting effect of postpartum infecundability is the largest. The effect of contraception is small.

II. TFR 4.5–6.0: The effect of postpartum infecundability (breastfeeding and postpartum sexual abstinence) decreases as the effect of contraception increases. Conversely, the effect of sexual exposure increases as the age at first union is delayed.

III. TFR 3.0–4.5: The fertility-inhibiting effect of both contraception and sexual exposure increases compared to Phase II. A small effect of abortion can also be found.

IV. TFR less than 3.0: The fertility-inhibiting effect of contraception is the largest, while that of postpartum infecundability is the smallest. The effect of abortion is greater than in Phase III, while the effect of sexual exposure is similar to that in Phase III.

Fertility transition in some countries has been analyzed using the Bongaarts' proximate determinants framework at the national and subnational level. In Ethiopia, a country in Phase II of the transition, contraceptive use was the primary driver of fertility decline, with its fertility-inhibiting effect rising from 15% to 37% over 15 years, although postpartum infecundability remained the strongest inhibitor overall (Ahmed Shallo 2020). In Pakistan, a country categorized in Phase III of transition according to Bongaarts' model, delayed marriage and contraceptive use were identified as central to fertility reduction, with urban areas advancing faster (Nasir et al. 2015). A regional analysis of Kenyan fertility, in Phase II at the time of the study, showed contraceptive use led declines in fertility in central regions, while increases in fertility were observed in coastal and western areas due to shorter breastfeeding durations and lower age at marriage (Anyara and Hinde 2006). In Bangladesh, a country in Phase IV of the transition, increases in fertility were explained by declining postpartum infecundability, inefficient contraceptive mixes, and higher sexual exposure (Rahman 2020). These findings highlight how proximate determinants interact differently across transition phases and how their effect varies within the same country, explaining different transitions at the subnational level.

The objective of this research is two-fold. First, we examine the patterns of fertility transition in capital cities, other urban areas, and rural areas in SSA, that is, whether these areas follow the patterns defined in the fertility transition model proposed in Bongaarts (1982). We analyze capital cities separately from other urban areas to go beyond the urban/rural dichotomy and test whether SSA capital cities are leading the fertility transition in SSA. Second, we study the role of the proximate determinants of fertility (Bongaarts 1978, 2015; Bongaarts and Potter 1983) in the fertility transition by place of residence. We specifically analyze how their fertility-inhibiting effects have contributed to fertility decline and to what extent these effects vary across the three subnational areas throughout the phases of the transition. In general terms, we expect that the fertility-inhibiting effects of the proximate determinants evolve with the fertility transition as predicted in the theoretical model (Bongaarts 1982; Bongaarts and Potter 1983). However, we also expect postpartum infecundability to continue to have a large effect on fertility at more advanced phases of the fertility transition, reflecting long duration of breastfeeding and postpartum sexual abstinence in SSA (Page and Lesthaeghe 1981; Todd and Lerch 2021). We do not anticipate a reduction in the fertility-inhibiting effect of postpartum infecundability, as an increase in the fertility-inhibiting effect of contraception is unlikely to offset it. This is because contraceptive use remains limited in many settings, even in the later stages of the transition.

3 | Data and Methods

3.1 | Data

We use data from 155 Demographic and Health Surveys (DHS) covering 34 countries (The DHS Program 2025). We include all SSA countries with at least two surveys, where it is possible to identify the capital or the largest city of the country and estimate the proximate determinants of fertility. These surveys were conducted between 1986 and 2024. They include information on birth histories, marital status, sexual activity, contraceptive use, number of years of education, breastfeeding, and postpartum abstinence for 171,361 women aged 15–49 living in the capital or largest city, 480,063 in other urban areas, and 1,116,403 in rural areas. We analyze the largest city rather than the capital when there are significant differences in population size. For instance, in Nigeria, we examine Lagos instead of Abuja, in South Africa, Johannesburg instead of Pretoria, in Tanzania, Dar es Salaam instead of Dodoma, Cotonou instead of Porto Novo in Benin, or Abidjan instead of Yamasukro in Côte d'Ivoire. Onwards, we refer to all capitals or largest cities as capital cities or capitals. Details are presented in Table 1.

3.2 | Methods

3.2.1 | *Proximate Determinants of Fertility*

The proximate determinants of fertility are behavioral or biological factors with a predictable effect that affect fertility. Changes in fertility can be accounted for by changes in four major proximate determinants (Bongaarts 1978, 2015; Bongaarts

TABLE 1 | List of Demographic and Health Surveys (DHS) used.

Country code	Country name	Capital or largest city	DHS used
AO	Angola	Luanda	2015-16, 2023-24
BF	Burkina Faso	Ouagadougou	1992-93, 1998-99, 2003, 2010, 2021
BJ	Benin	Cotonou	1996, 2001, 2006, 2011-12, 2017-18
BU	Burundi	Bujumbura	1987, 2010-11, 2016-17
CD	Congo D.R.	Kinshasa	2007, 2013-14, 2023-24
CG	Congo	Brazzaville	2005, 2011-12
CI	Côte d'Ivoire	Abidjan	1998-99, 2011-12, 2021
CM	Cameroon	Yaounde-Douala	1991, 1998, 2004, 2011, 2018-19
ET	Ethiopia	Addis Ababa	2000, 2005, 2011, 2016
GA	Gabon	Libreville-Port Gentil	2000-01, 2012, 2019-21
GH	Ghana	Accra	1988, 1993-94, 1998-99, 2003, 2008, 2014, 2022-23
GM	Gambia	Banjul	2013, 2019-20
GN	Guinea	Conakry	1999, 2005, 2012, 2018
KE	Kenya	Nairobi	1988-89, 1993, 1998, 2003, 2008-09, 2014, 2022
KM	Comoros	Moroni	1996, 2012
LB	Liberia	Monrovia	1986, 2006-07, 2013, 2019-20
LS	Lesotho	Maseru	2004-05, 2009-10, 2014, 2023-24
MD	Madagascar	Antananarivo	1992, 1997, 2003-04, 2008-09, 2021
ML	Mali	Bamako	1987, 1995-96, 2001, 2006, 2012-13, 2018, 2023-24
MW	Malawi	Lilongwe	1992, 2000, 2004-05, 2010, 2015-16,2024
MZ	Mozambique	Maputo	1997, 2003-04, 2011, 2022-23
NG	Nigeria	Lagos	1990, 2003, 2008, 2013, 2018, 2024
NI	Niger	Niamey	1992, 1998, 2006, 2012
NM	Namibia	Windhoek	1992, 2000, 2006-07, 2013
RW	Rwanda	Kigali	1992, 2000, 2005, 2010-11, 2014-15, 2019-20
SL	Sierra Leone	Freetown	2008, 2013, 2019
SN	Senegal	Dakar	1992-93, 1997, 2005, 2010-11, 2012-13, 2014, 2015, 2016, 2017, 2018, 2019, 2023
TD	Chad	Ndjamena	1996-97, 2004, 2014-15
TG	Togo	Lomé	1988, 1998, 2013-14
TZ	Tanzania	Dar es Salaam	1991-92, 1996, 1999, 2004-05, 2009-10, 2015-16, 2022
UG	Uganda	Kampala	1988-89, 1995, 2006, 2011, 2016
ZA	South Africa	Johannesburg	1998, 2016
ZM	Zambia	Lusaka	1992, 1996-97, 2001-02, 2007,2013-14, 2018-19, 2024
ZW	Zimbabwe	Harare	1988-89, 1994, 1999, 2005-06, 2010-11, 2015

and Potter 1983). The fertility-inhibiting effect of each proximate determinant can be represented by an index that varies between 0 and 1, where 1 indicates no fertility inhibition and values below 1 indicate some fertility-inhibiting effect. The TFR can be expressed as the product of the four indices and total fecundity (TF). TF represents the average maximum number of children women could have in their lifetime in the absence of fertility-inhibiting effects:

$$TFR = C_m \times C_c \times C_i \times C_a \times TF \tag{1}$$

Where, C_m is the index of sexual exposure, C_c the index of contraception, C_i the index of postpartum infecundability, and C_a the index of abortion. All four indices can be estimated using the DHS. We calculate them by subnational area following Bongaarts' revised model of the proximate determinants of fertility (Bongaarts 2015):

- C_m measures the sexual exposure. C_m includes in-union women and not-in-union women who are pregnant, report sex in the last month, use contraception, or are postpartum infecundable:

$$C_m = \sum C_m(a) \frac{f_m(a)}{\sum f_m(a)}$$

Where $C_m(a)$ is the sexual exposure index by age group and $f_m(a)$ is the age-specific fertility rate among exposed women.

- C_c measures the impact of contraception, accounting for the average effectiveness of the method used and the overlap with postpartum infecundability. We use the average effectiveness (e) proposed in Stover (1998), as it includes a more comprehensive list of contraceptive effectiveness measures than the one used in Bongaarts (2015) and Bongaarts and Potter (1983):

$$C_c = \sum C_c(a) \frac{f_f(a)}{\sum f_f(a)}$$

Where $C_c(a)$ is the contraception index by age group and $f_f(a)$ is the fecundity rate by age group provided in Bongaarts (2015). The contraception index by age group is calculated as $C_c(a) = 1 - r(a)[u(a) - o(a)]e(a)$, where $r(a)$ is the fecundity adjustment by age group estimated in Bongaarts (2015), $u(a)$ is the contraceptive prevalence among exposed women by age group, $e(a)$ is the average contraceptive effectiveness by age group, and $o(a)$ is the overlap with postpartum infecundability by age group.

- C_i captures the extent to which postpartum abstinence and lactational amenorrhea inhibit fertility:

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

Where i is the mean duration of postpartum infecundability. The mean duration is the number of births at specified times before the survey for which the mother is either postpartum amenorrheic (i.e., her menstrual period has not resumed since the birth, and she is not currently pregnant) or abstaining (i.e., mother has not resumed sexual intercourse since the birth).

- C_a captures induced abortion:

$$C_a = \frac{TFR}{TFR + b \times TAR}$$

Where $b = \frac{14}{18.5 + i}$ is the number of births averted by abortion, i is the average duration of postpartum infecundability, and TAR is the Total Abortion Rate. Bongaarts (2015) estimates TAR as 30 times the average annual number of abortions per 1,000 women aged 15–45 divided by 1,000. The average annual number of abortions for individual countries is obtained from the Guttmacher Institute Data Center (Guttmacher Institute 2024). In our case, we use a different method to estimate TAR since the published abortion data corresponds to the period 2015–2019 and we considered that using the same rates for surveys from 30 years ago could be unrealistic. We instead use the method proposed by Westoff (2008):

$$TAR = 2.94 - 0.033(MOD) - 0.252(TFR) + 0.091(YRSEDUC) \tag{2}$$

Where MOD is the percentage of use of modern contraceptives and YRSEDUC is the average number of years of education for women 15 years and older. We have compared TAR estimates at the national level from both methods using surveys in the period 2015–2019 and results are similar, suggesting that the estimation of C_a using the TAR from equation 2 is robust.

Following Bongaarts' approach (Bongaarts 1978, 2015; Bongaarts and Potter 1983), TF can be computed from TFR and proximate determinants as:

$$TF = \frac{TFR}{C_m \times C_c \times C_i \times C_a} \tag{3}$$

Bongaarts (2015) calculates the TF for each survey (i.e., at the national level) and then estimates a single TF for all countries from an unweighted average, resulting in 15.4. We follow the same approach using Equation 3 to calculate the TF. Our average TF value is 15.8. We use the same TF for the three subnational areas as we consider that there is no reason why the maximum number of children a woman can have in the absence of fertility inhibitors, i.e. the TF, should differ between them. Differences in estimates by subnational area could be due to environmental factors, but mostly to measurement error in the proximate determinants and fertility rates. At the national level, the unweighted average of observed TFR across all countries is 4.62 children per woman and the unweighted average of estimated TFR using Equation 1 is 4.68. In capital cities, the unweighted average of observed TFR is 3.68 and the unweighted average of estimated TFR is 3.86. In other urban areas, the unweighted average of observed TFR is 4.33 and the unweighted average of estimated TFR is 4.44. In rural areas, the unweighted average of observed TFR is 5.96 and the unweighted average of estimated TFR is 5.72. We acknowledge potential measurement errors in the estimation of the indices of proximate determinants, particularly in the abortion index, and we are aware that the effect of abortion might become more relevant in capitals and in more progressed phases of fertility transition (Guillaume 2003).

3.2.2 | *Fertility Inhibition of Proximate Determinants*

The number of children avoided due to the fertility-inhibiting effect of proximate determinants can be estimated from TFR (equation 1), TF (equal to 15.8), and the proximate determinants (Bongaarts 1982):

- Sexual exposure: $\frac{TFR}{C_m} - TFR = TF \times C_a \times C_c \times C_i - TFR$
- Abortion: $\frac{TFR}{C_m \times C_a} - \frac{TFR}{C_m} = TF \times C_c \times C_i - \frac{TFR}{C_m}$
- Contraception: $\frac{TFR}{C_m \times C_c \times C_a} - \frac{TFR}{C_m \times C_a} = TF \times C_i - \frac{TFR}{C_m \times C_a}$
- Postpartum infecundability: $\frac{TFR}{C_m \times C_a \times C_c \times C_i} - \frac{TFR}{C_m \times C_a \times C_c} = TF - \frac{TFR}{C_m \times C_a \times C_c}$

4 | Results

Fertility transition in SSA is underway, although the stage of the transition differs across countries and subnational areas. Table 2 summarizes the number of subnational areas by phase of the transition and Figure 1 shows the phase of transition by subnational area in the most recent survey for each country (102 observations, 3 for each of the 34 countries). The results show that the fertility transition across subnational areas occurs as argued by stylized models (Dyson 2011; Shapiro and Tambashe 2002), i.e., capital cities tend to be one phase further in the transition than other urban areas and two phases further than rural areas of the same country. Most capitals are in the most advanced stages of the transition: 17 capitals are in Phase III and 14 capitals are in Phase IV. TFRs in capital cities range from 1.8 children per woman in Addis Ababa (Ethiopia) to 5.3 children per woman in Niamey (Niger). Regarding geographic patterns, capitals located in Eastern and Southern Africa are in Phase IV. Except for Ndjamena (Chad) that is in Phase II, capitals in Middle Africa are in Phase III. Capitals in Western Africa are distributed from Phase II to Phase IV, although most of them are in Phase III. No capital is in Phase I of the fertility transition. Most of other urban areas are in Phase III of the transition (22 out of 34 countries). TFRs in other urban areas range from 2.0 children per woman in Lesotho to 5.8 children per woman in Niger. As in the case of capital cities, no other urban area is in Phase I of the transition. In contrast, rural areas in eight countries are still in Phase I, all of them located in Middle and Western Africa. TFRs in rural areas range from 2.8 children per woman in Lesotho (Phase IV) to 8.1 children per woman in Niger (Phase I). Most of rural areas ($n = 21$) are in Phase II, and only the rural area of Lesotho is in phase IV.

Figure 2 presents the estimated indices of the proximate determinants of fertility by phase of fertility transition according to subnational areas. In this graph, the lower the value of the index, the higher the fertility-inhibiting effect. In addition, Figure 2 shows the distribution of the indices across phases and subnational areas. We note that the estimates of C_a (abortion) and C_i (infecundability) tend to be tightly clustered around the median with a few outliers. Conversely, estimates of C_m and C_c have a larger dispersion and that is true for all subnational areas and phases of the transition. This means that in certain subnational areas of some countries, the effect of contraception does not inhibit fertility as much as in some areas of other countries, and therefore, the lower inhibiting effect should be offset by a higher inhibiting effect of another proximate determinant. We observe that estimates of C_m decrease in all subnational areas as the transition progresses, which is largely explained by the proportion of sexually active women and age at first union in each phase of the transition. On average, 93.0% of women are sexually active in Phase I and 84.4% in Phase IV. In addition, the mean age at first union is 17.7 years in Phase I and increases to 21.5 years in Phase IV. The decrease in C_c as the transition progresses is explained by the increase in contraceptive prevalence. On average, 14.8% of women use any contraceptive method (and 9.7% use any modern method) in Phase I, while 42.3% of women use any contraceptive method (and 39.0% use any modern method) in Phase IV. In Figure 2, we also observe the decrease in C_a as the transition progresses, explained by the changes in TAR. On average, TAR increases from 1.2 abortions per 1,000 women in Phase I to 1.9 abortions per 1,000 women in Phase IV. Estimates of C_i slightly increase between Phase I and Phase IV of the transition. This is correlated with small decreases in the duration of postpartum infecundability, which declines from an average of 15.3 months in Phase I to 12.3 months in Phase IV.

Relationships between the fertility-inhibiting effects (number of children avoided) of the proximate determinants in different phases of the fertility transition by subnational area are presented in Figure 3. In this graph, results include all surveys for all countries and correspond to the phase at the time of the survey (see distribution in Appendix Table 1). The results show that the inhibitory effect of three of the proximate determinants, C_m, C_a and C_c, vary as expected during the fertility transition, but the magnitude of their effects varies across subnational areas. We find that, in all subnational areas, the number of children averted by contraception increases significantly as transition progresses, and is the single most important determinant in fertility declines. The inhibiting effect of abortion also increases as transition progresses, and that this effect is larger in capital cities than in other urban areas and rural areas. Although contraception and abortion are the main drivers of fertility *declines*; the effect of postpartum infecundability remains the main inhibitor of fertility *levels* in all phases and subnational areas, and has changed only slightly. In other

TABLE 2 | Distribution of subnational areas by phase of the fertility transition in the most recent survey for each country.

	TFR	Capital cities	Other urban areas	Rural areas	National level
Phase I	> 6.0	—	—	8	3
Phase II	4.5–6.0	3	7	21	13
Phase III	3.0–4.5	17	22	4	16
Phase IV	< 3	14	5	1	2

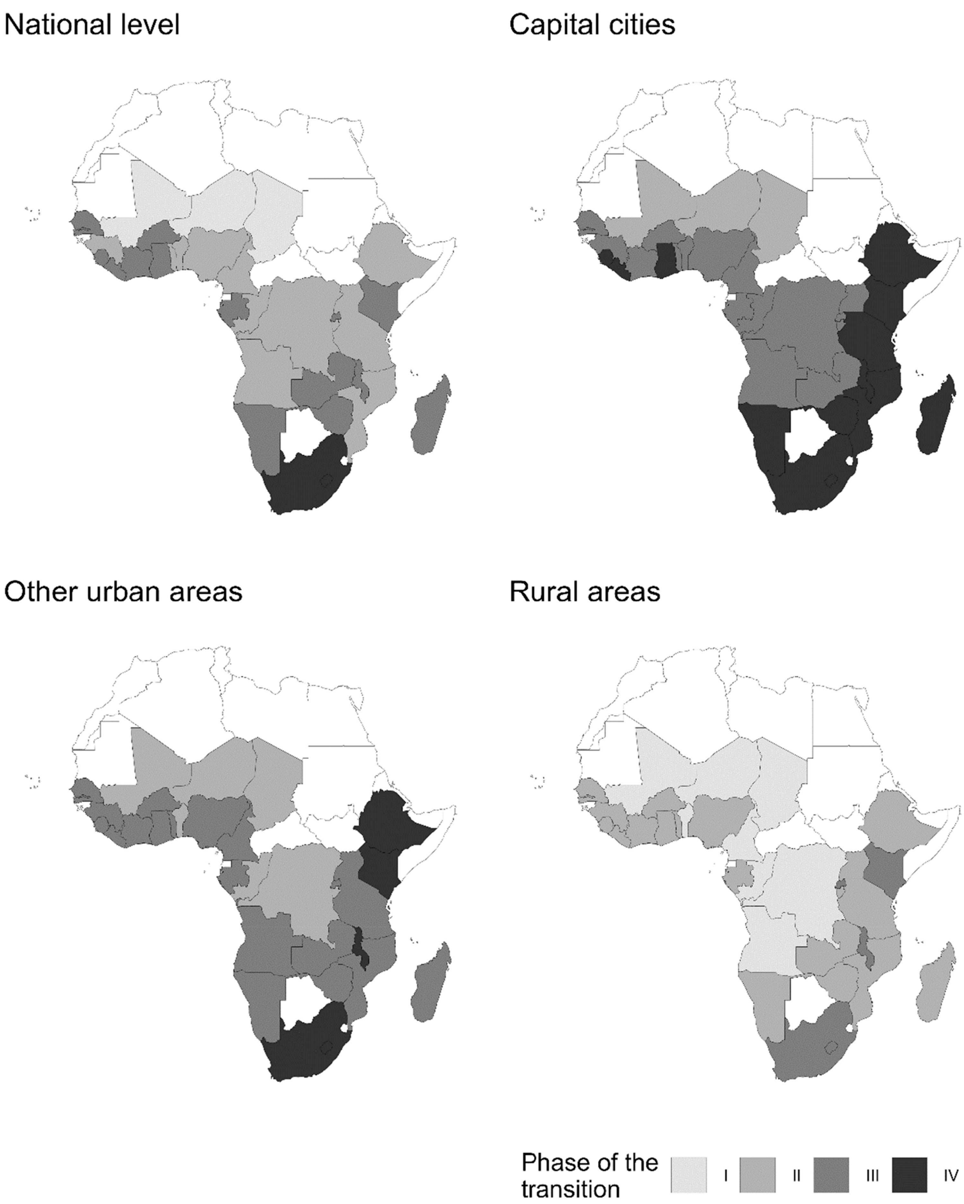

FIGURE 1 | Phase of fertility transition in the most recent survey by subnational area.

words, the decline in the effect of postpartum infecundability does not fully align with the theoretical model of the fertility transition, as a sharp decrease from Phase I to Phase IV would have been expected. This suggests that sub-Saharan Africa may be exceptional in this regard. Results presented in Figure 3 are consistent with patterns of proximate determinants in Figure 2.

The upper panel of Figure 4 complements this information with the distribution of the number of children averted by the fertility-inhibiting effect of the proximate determinants by subnational areas. The inhibiting effect of sexual exposure is similar across subnational areas, but slightly higher in capital cities. On average, lower sexual exposure averts 1.9 children per woman in capital cities, which is 0.4 more children than in rural areas, and reflects later age at union in urban areas. Fertility inhibited by abortion is highest in capital cities and twice as high as in rural areas. On average, induced abortion averts 1.6 children per woman in capital cities and 0.7 children per woman in rural areas. The inhibitory effect of contraception is clearly larger in capital cities – more often at advanced stages of the fertility transition – than in the other two subnational areas. Contraception averts on average 3.4 children per woman in capital cities, 3.0 in other urban areas, and 2.1 in rural areas. In the three subnational areas, postpartum infecundability is the proximate determinant with the largest inhibitory effect on fertility. The largest inhibitory effect of postpartum infecundability is found in rural areas, where 6.3 children per woman are averted. It also remains very large in other urban areas and capital cities, where more than five children are averted because of postpartum infecundability. Up to now, the number of births averted because of this proximate determinant has been fairly stable. Should it decrease, it could lead to higher fertility.

The bottom panel of Figure 4 shows the distribution of the number of children averted by the fertility-inhibiting effect of the proximate determinants by phase of fertility transition. As predicted by Bongaart's theoretical model (Bongaarts 1982), fertility inhibited by sexual exposure is slightly lower in Phase I than in other phases of the transition. On average, 1.3 children per woman are averted in Phase I, while 1.7 are averted in

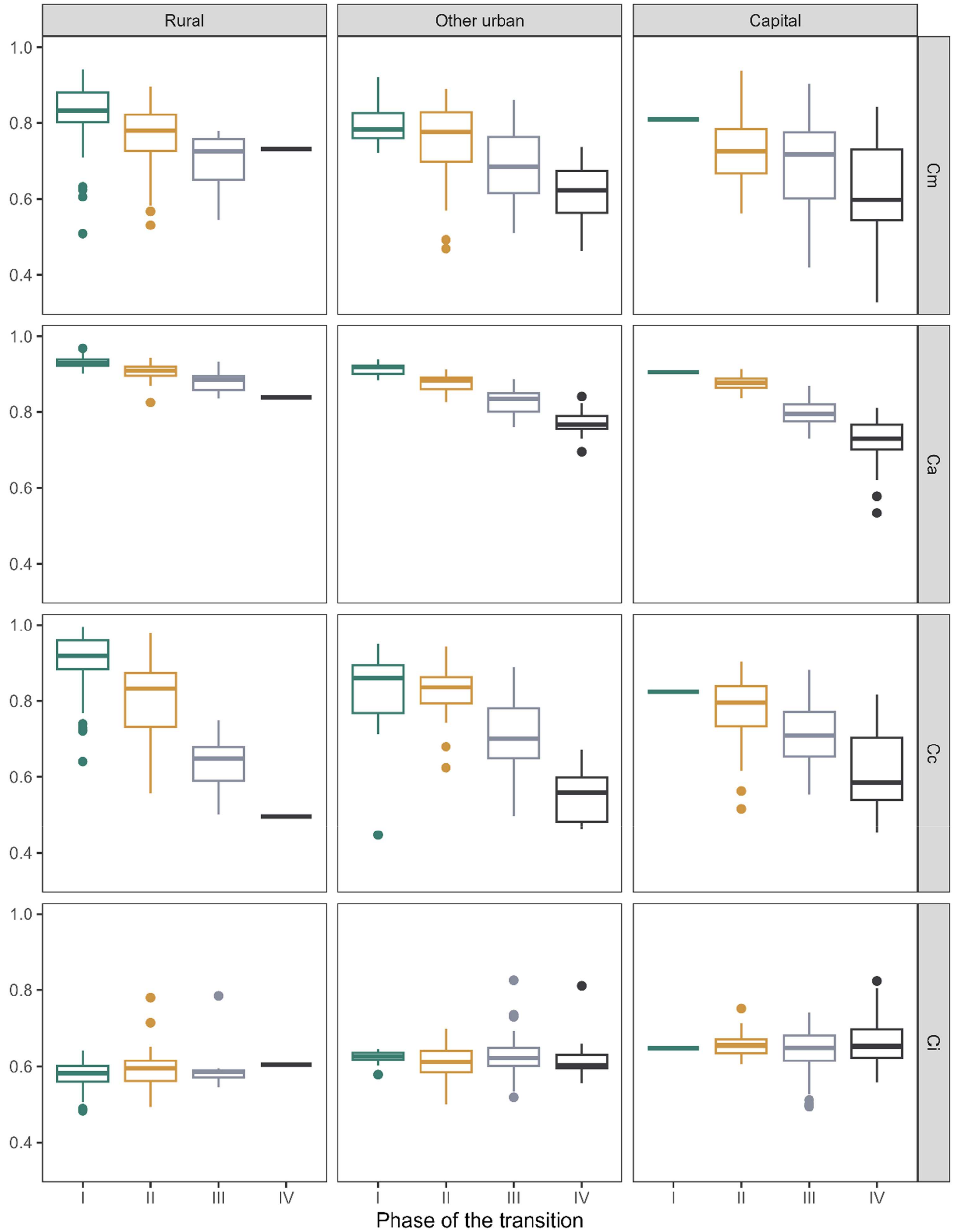

FIGURE 2 | Indices of the proximate determinants of fertility by phase of fertility transition according to subnational areas.

Phase II and Phase IV and 1.8 in Phase III. Fertility inhibited by abortion increases as the transition progresses. Abortion averts an average of 0.6 children per woman in Phase I, and its inhibiting effect almost triples to 1.6 children per woman averted in Phase IV. The number of children averted because of contraception increases sharply as the transition progresses. On average, the effect of contraception averts 1 child per woman in Phase I, 1.9 children per woman in Phase II, 3 in Phase III, and 4.2 in Phase IV. As the theoretical model predicted, the effect of postpartum infecundability decreases as the transition progresses, although the decline is rather modest. Therefore, postpartum infecundability still accounts for the largest fertility inhibition, even in the most advanced stages of the transition. On average, the effect of postpartum infecundability averts 6.6 children per woman in Phase I and decreases to 5.5 children in Phase IV.

Figure 5 illustrates the trends in fertility rates and the changes in the fertility-inhibiting effects of proximate determinants of fertility by subnational area, enabling us to visualize the shifts over time. Trends were smoothed using restricted cubic splines from pooled data, with the estimates of the proximate determinants as the dependent variables and year as the independent variable. First, smoothed values of each proximate determinant by year were estimated. Then, fertility inhibition of the proximate determinants was calculated for each year using the smoothed estimates. Results show that TFRs have declined in all three subnational areas since the mid-1980s (yellow areas), but a slowdown in decline is observed in the 2000s in all three areas. The same graph also shows trends in fertility reduction due to the effect of proximate determinants. The changes in the areas associated with the fertility-inhibiting effects of the proximate determinants (shades of blue) show how

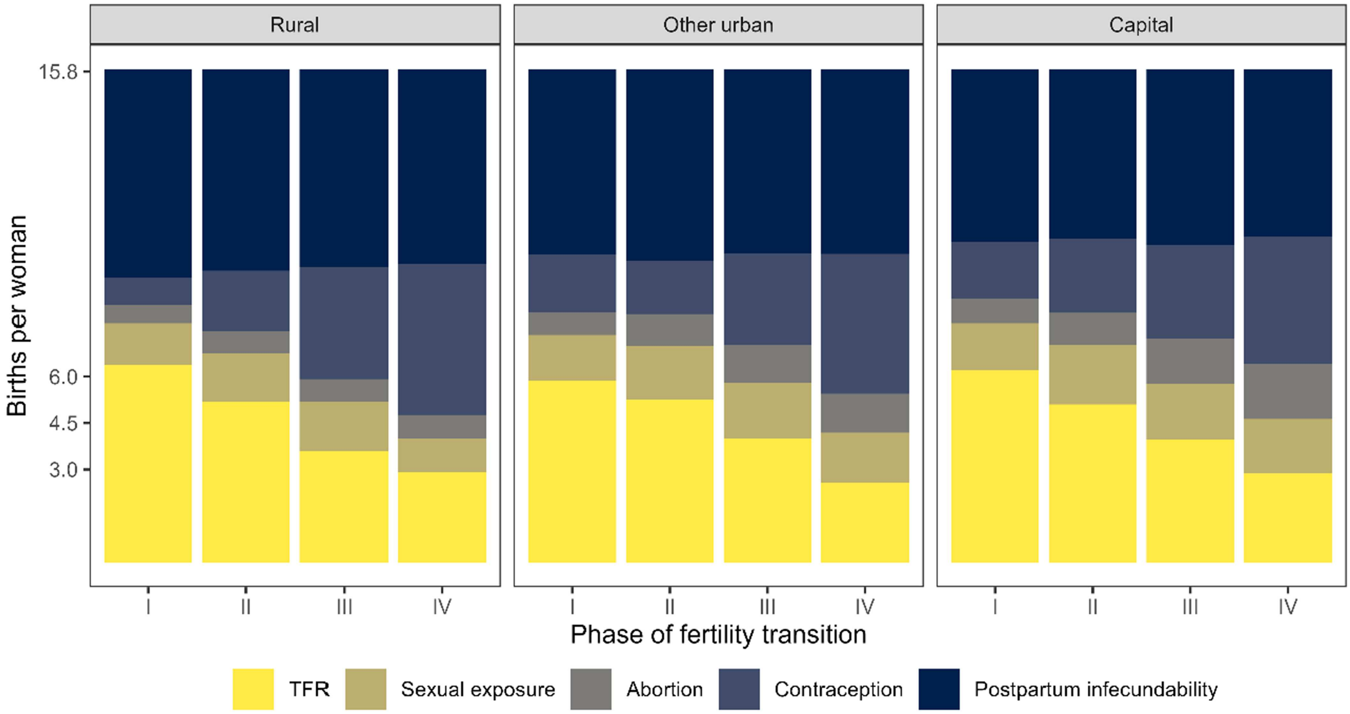

FIGURE 3 | Relationships between the fertility-inhibiting effects of the proximate determinants in different phases of the fertility transition by subnational area.

fertility inhibition has changed over time and in which subnational area its effect is largest. We observe that the inhibiting effect of contraception is greater in the capital cities, and has been so throughout the period analyzed. However, we also note a significant increase in its inhibiting effect in rural areas in recent years.

Figure 6 presents trends in fertility rates and fertility-inhibiting effects of proximate determinants of fertility by subnational area in five selected countries of SSA. The numbering in Roman numerals corresponds to the phase of the transition from the most recent survey. Fertility transitions in these five countries span a wide range of phases and trends in the fertility-inhibiting effects of proximate determinants. As mentioned above, all countries follow the pattern predicted by stylized fertility transition models: fertility first declines in urban areas, followed by rural areas. Thus, capital cities are usually one phase ahead of other urban areas and two phases ahead of rural areas, but in no case the other way around. From the most recent DHS, Niger is a country in the earliest phase of the fertility transition, with a TFR of 7.6 children per woman. Its capital, Niamey, and the other urban areas are in Phase II and the rural areas are in Phase I of the fertility transition. As for Benin, it has a national TFR of 5.7 children per woman. At the subnational level, Cotonou is in Phase III, other urban areas are in Phase II, and rural areas are in Phase I. In Ghana, Accra is in Phase IV, other urban areas are in Phase III, and rural areas are in Phase II. In Kenya, Nairobi and other urban areas are in Phase IV and rural areas are in Phase III. Finally, Lesotho is the only country in SSA where all subnational areas are in Phase IV of the transition. Notably, our analysis from the most recent survey reveals that the capital cities of Lesotho (Maseru, TFR = 2.2), Ethiopia (Addis Ababa, TFR = 1.8) and Mozambique (Maputo, TFR = 2.1), are the only ones with TFRs close to or below the replacement level. TFR by subnational level for all countries is presented in Appendix Table 2.

As observed in Figure 6, Kenya could be considered a textbook example. As predicted by Bongaarts model (Bongaarts 1982), as the fertility transition progresses, the fertility-inhibiting effect of contraception increases to become the most relevant inhibiting effect in the final phase of the transition, offsetting the fertility inhibiting effect of postpartum infecundability. And this is true in all three Kenyan subnational areas. In contrast, in other countries the inhibiting effect of contraception increases as the fertility transition progresses, but the greatest inhibiting effect is that of postpartum infecundability, which is a common feature for virtually all subnational areas, even at the most advanced stages of the transition. In Lesotho, despite the fact that all subnational areas are in the most advanced phase of transition, inhibited fertility is largely explained by the inhibiting effect of postpartum infecundability. We note the same pattern in Accra (capital of Ghana) and in Cotonou (capital of Benin). On the other hand, but also as predicted by Bongaarts model (Bongaarts 1982), in the earlier stages of the transition – such as in all subnational areas of Niger, other urban areas and rural areas in Benin, or rural areas in Ghana – the inhibiting effect of sexual exposure is the second most relevant fertility inhibitor. Trends in fertility rates and changes in the fertility-inhibiting effects of proximate determinants for all countries by subnational area and phase of the transition are presented in Appendix Figures 1–3. We find that the subnational areas that have made the most rapid progress in the transition are those with a sharp increase in the fertility-inhibiting effect of contraception.

5 | Conclusions

The fertility transition is underway in SSA. Only a few countries are still in the earliest stage of transition, i.e. with a national

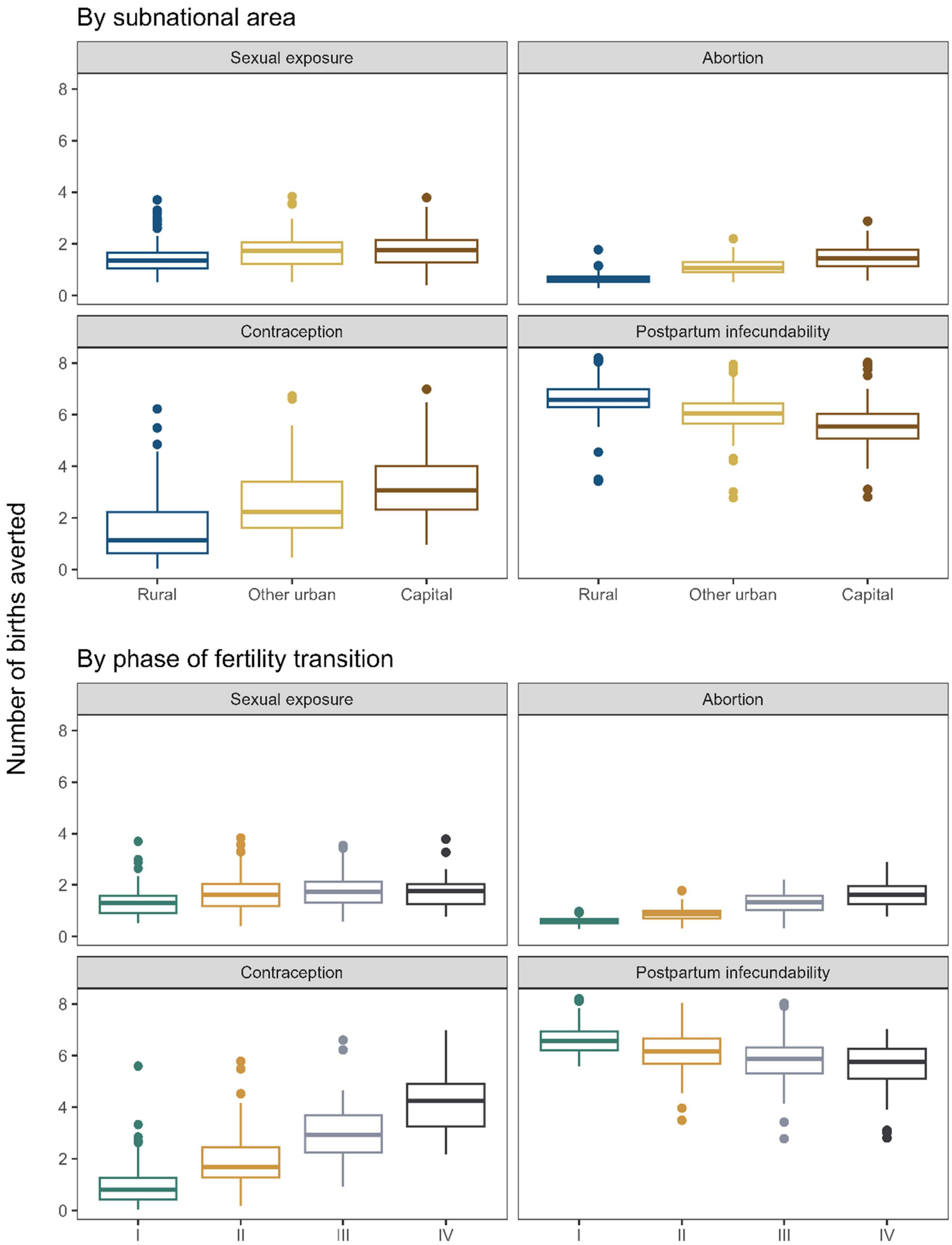

FIGURE 4 | Fertility-inhibiting effects of the proximate determinants by subnational area and phase of fertility transition.

TFR above 6 children per woman. Consistent with stylized fertility transition models that predict that fertility declines first in urban areas and then in rural areas (Dyson 2011; Shapiro and Tambashe 2002), our findings confirm that capital cities lead the fertility transition in SSA, followed by other urban areas and rural areas. Capital cities tend to be one phase further in the transition than other urban areas and two phases further than rural areas of the same country. Capital cities usually have a higher concentration of people in better socioeconomic conditions. Previous research shows that better-off women, i.e., those with higher levels of wealth and education, have lower fertility rates (Corker et al. 2022; Schoumaker and Sánchez-Páez 2024) and that increased schooling leads to reductions in fertility (Schoumaker and Sánchez-Páez 2026; Shapiro 2012).

Most capitals of the countries included in our study are in the most advanced stages (III or IV) of the transition, especially those in Eastern and Southern Africa. In contrast, most rural areas are in the earliest stages (I or II) of the transition, especially those in Middle and Western Africa. In fact, transitions in contraceptive use have also been slower in these two subregions (Dasgupta et al. 2022). Interestingly, the national transition phase coincides with that in rural areas in many countries (see the color patterns in Figure 1). Further research is needed to understand the extent to which rural fertility trends influence national-level fertility trends, as well as whether the decline in fertility in capital cities affects the decline (or the lack of it) in rural areas (diffusion effects). A decomposition approach would allow measuring the contribution of the largest population subgroup – the rural dwellers (United Nations 2018) – on national fertility trends. As shown in Appendix Figures 4 and 5, the total fertility rate in most countries largely reflects births in rural areas, and changes in rural areas are expected to be the main drivers of aggregate fertility changes.

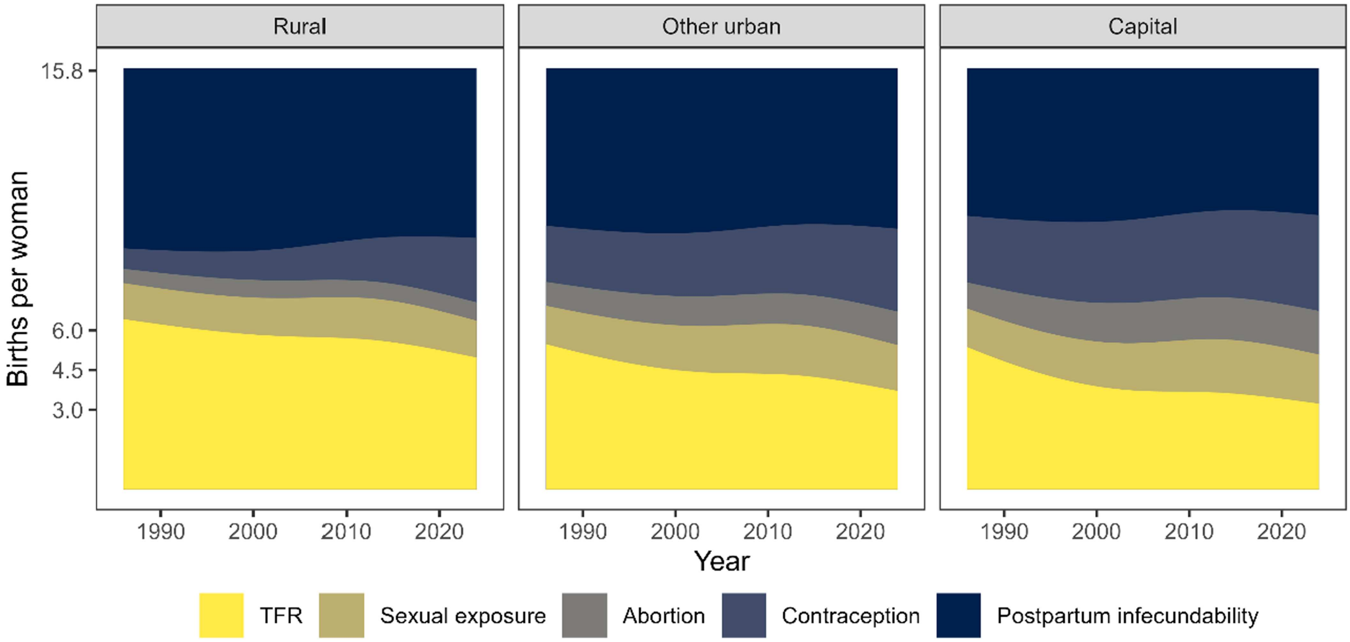

FIGURE 5 | Trends in fertility rates and fertility-inhibiting effects of the proximate determinants by subnational area.

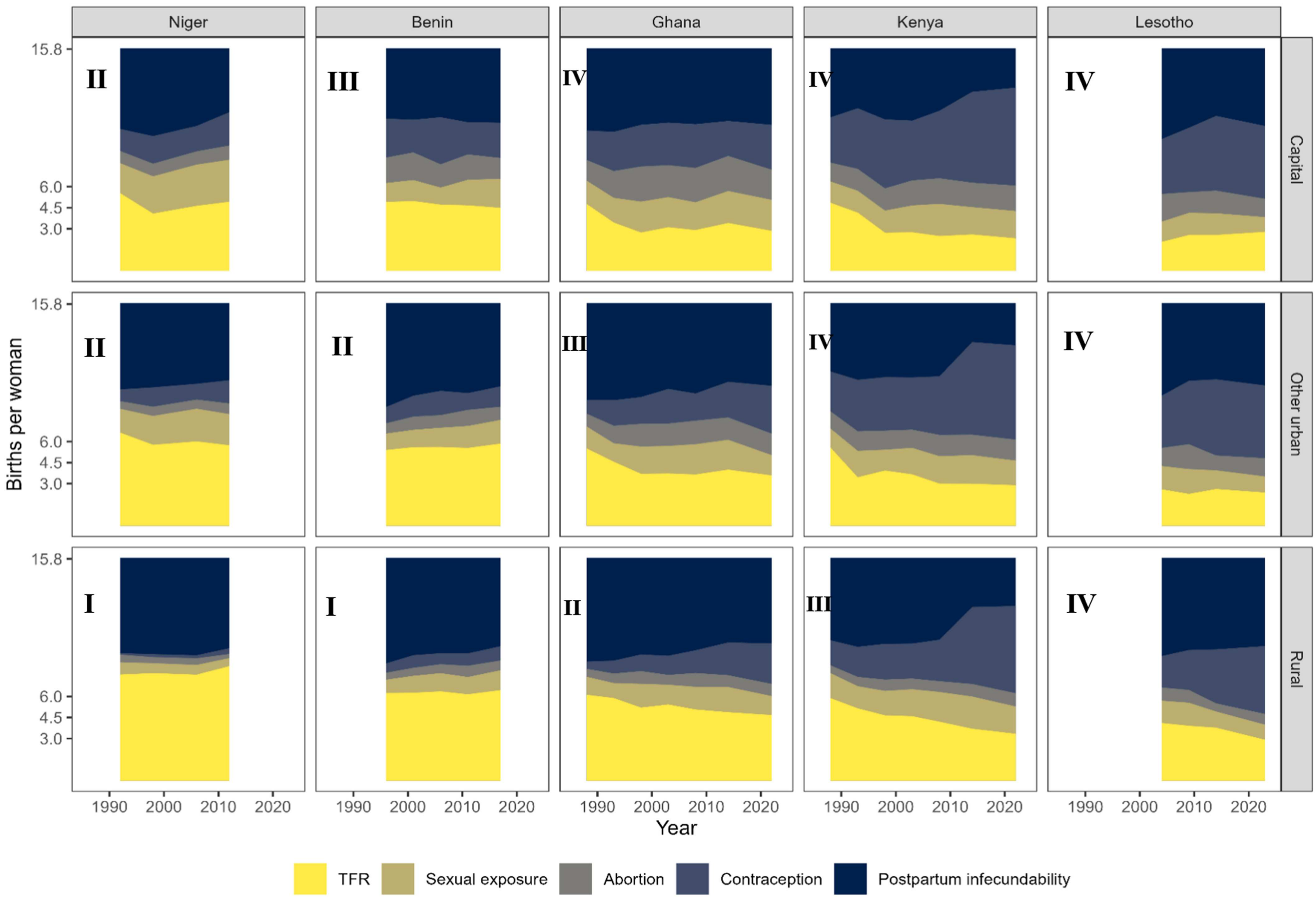

FIGURE 6 | Fertility transition by subnational area in selected countries of sub-Saharan Africa. The numbering in Roman numerals corresponds to the phase of the transition from the most recent survey.

Our findings show that, overall, the inhibitory effect of most proximate determinants evolves according to the model proposed by Bongaarts (1982). The number of children inhibited by contraception and abortion increases as transition progresses. We observe that abortion is more frequent in capital cities than in rural areas and that capitals that have made the most rapid progress in the transition are those with a sharp increase in fertility inhibited by the effect of contraception. In addition, sexual exposure inhibits fertility similarly in all phases on average. However, there are cases where the fertility transition follows different patterns as the inhibitory effect of each proximate determinant at each stage of the transition varies across countries. For example, the inhibitory effect of sexual exposure leads the transition in Niger, the inhibitory effect of abortion largely explains the inhibition of fertility in Ghana, the inhibitory effect of contraception mainly inhibits fertility in Benin and Kenya, or fertility inhibited by the effect of postpartum infecundability accounts for fertility rates in Lesotho.

Nevertheless, a common feature across countries and subnational areas is that the inhibitory effect of postpartum infecundability is high even at the most advanced stages of fertility transition. All in all, we find that the index of postpartum infecundability varies little by phase of fertility transition in all three subnational areas. Fertility inhibited by postpartum infecundability is expected to decrease as transition progresses until it has the smallest inhibitory effect in the last phase of the transition (Bongaarts 1982). The inhibitory effect of postpartum infecundability is particularly high, as that the duration of postpartum abstinence and breastfeeding is exceptionally long in SSA. As the fertility transition progresses, the increase in contraceptive use is expected to offset the shortening of postpartum infecundability periods. However, as Todd and Lerch (2021) pointed out, the limited use of contraceptives in sub-Saharan Africa is offset by extended periods of breastfeeding and abstinence, not the other way around. This peculiarity in SSA may imply that a change in postpartum behaviors could lead to an increase in fertility rates. Reducing the duration of postpartum infecundability without offsetting it with an increase in contraceptive use leaves open the possibility of further fertility stalls or longer-lasting current stalls.

A great advantage of the DHS is that the standardized methodology limits comparability issues across countries. Yet, we acknowledge that DHS data are subject to limitations. Birth histories may be affected by underreporting and displacement of births potentially affecting fertility-related estimates (Schoumaker 2014). Additionally, the estimation of proximate determinants of fertility may be affected by misreported contraceptive use (e.g., incorrect method classification, inaccurate effectiveness rates, or inconsistent reporting), errors in the retrospective reporting of postpartum amenorrhea and abstinence, and misleading assumptions about sexual activity (e.g., the assumption that all married women are sexually active). The measurement of abortion is also a challenge. We did not estimate the abortion index from observed or reported data, but from an empirical model (Westoff 2008). While these abortion rates are "essentially unverifiable" (Westoff 2008: 19) in most counties, they are plausible and consistent with those available elsewhere (e.g., Guttmacher Institute 2024). Considering these limitations, country-level estimates may need to be interpreted with caution in some cases, especially when changes are erratic. However, the "big picture" is less sensitive to country-specific errors, and the limitations we have mentioned are unlikely to alter our substantive conclusions.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are openly available in The DHS Program at https://www.dhsprogram.com/data/available-datasets.cfm.

Endnotes

[1] The mean duration of postpartum infecundability is calculated as described in the Guide to DHS Statistics (Croft et al. 2023) for indicator 5.32 "Median and mean durations of postpartum amenorrhea, abstinence, and insusceptibility".

[2] A perfect model would show no difference between the two values. However, there are several possible explanations for the discrepancies (Bongaarts 2015): 1) errors in the estimates of the TFR (both sampling and non-sampling), 2) errors in measures of the proximate determinants, 3) errors in the model equation for estimating the indices and TF, and 4) true variation in TF due to differences in the frequency of intercourse and sterility. Our estimates show a difference of 0.04, similar to the estimate in Bongaarts (2015).

[3] This TFR estimate corresponds to 2012. A more recent survey from 2021 calculates the TFR in Niger to be 6.2 children per woman, which also corresponds to Phase I of the transition. The latest survey has not been used, as it does not include all the information needed to estimate the proximate determinants.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.
Appendix_figures_rev. Appendix_tables_rev.