The role of the proximate determinants and ideal family size on fertility stalls in capital cities of sub-Saharan Africa

David A. Sánchez-Páez[1]* and Bruno D. Schoumaker[1]

Preliminary version

Abstract

Background: Fertility in sub-Saharan Africa has stalled since the early 2000s. Studies to determine when and where the stalls are have mainly focused at the national level. Little is known about fertility stagnations in the capital cities and the reasons behind them.

Data and methods: We use 116 DHS surveys from 30 sub-Saharan countries. Focusing only on the capital cities, we aim to find associations between fertility stalls periods and the proximate determinants of fertility and ideal family size. We propose scenarios to simulate the potential effect of changes in the determinants of fertility.

Results: The proximate determinants of fertility and ideal family size are highly correlated with periods of fertility stalls. On average, increases of 10% in sexual exposure or contraception indexes would lead to the rise of TFR in 0.40 and 0.44, respectively. The same increase in postpartum insusceptibility would add 0.26 to TFR. One child more in the desired family size would increase TFR in 0.24.

Discussion: Sexual activity is positively correlated to fertility stalls. Also, meeting contraceptive needs would have helped to avoid periods of fertility stagnation or, at least, to reduce their intensity. Moreover, the decreased length of postpartum insusceptibility has contributed to plateauing. There is a correlation between the invariance of the ideal family size over time and periods of non-decreasing fertility.

1. Introduction

Fertility in sub-Saharan Africa (SSA) started declining substantially in the late 1980s, later and at a slower pace than in other regions. In the early 2000s, fertility stalls were identified in several countries of SSA. The first countries were Ghana and Kenya (Bongaarts 2006; Westoff and Cross 2006), and then as many as 20 countries have been classified in the stalled category at some point (e.g., Bongaarts 2008; Ezeh, Mberu, and Emina 2009; Garenne 2008; Schoumaker 2019). Recently, the cases of fertility stalls were evaluated in order to confirm if they were real or spurious (Schoumaker 2019). As a result, their number was revised downward and were limited to six countries strongly supported by the data —Cameroon,

---

[1] Center for Demographic Research – DEMO, Université Catholique de Louvain.
* david.sanchezpaez@uclouvain.be

Congo, Kenya, Namibia, Zambia, and Zimbabwe— and to six countries where evidence is moderate —Côte d'Ivoire, Gabon, Madagascar, Nigeria, South Africa, and Tanzania—. Stalls are thus not as widespread as initially thought, but they are not exceptional either. The strong influence of these stalls on population growth and their potential adverse effects on SSA development has led researchers to take an interest in the possible causes of stagnation.

National estimates usually hide the heterogenity found at the subnational level, for instance, fertility is lower in urban areas than in rural areas (Bocquier and Schoumaker 2018). Despite the dissimilarities by place of residence, research on fertility stalls in SSA has mainly been conducted at the national level. Stalls in urban areas have, for the most part, been ignored (Garenne 2011), eventhough capital cities usually concentrate a significant share of population and lead fertility transitions due to better access to education, health services, and family planning (Lerch 2019). In this regard, evidence of fertility stagnation was found in urban areas between 10 and 20 years ago (Garenne and Joseph 2002; Shapiro and Tambashe 2002; Shapiro and Gebreselassie 2008). Since then, no further research has been conducted to understand how fertility trajectories behave at the subnational level, until a recent study found that stalls are more common in capital cities than in other urban or rural areas (Schoumaker and Sánchez-Páez 2020). However, the reasons behind this pattern in the fertility of capital cities have not yet been clarified.

From the fertility transition perspective, it should be expected declines in fertility until reaching the replacement level, first in urban areas, and later in rural areas (Garenne and Joseph 2002; Shapiro and Tambashe 2002). For instance, very low fertility rates have been already found in Addis Ababa (Kinfu 2000) and Accra (Blanc and Gray 2002). However, in the rest of SSA capital cities, fertility has stalled and it has occurred at much higher levels than the replacement rate (Schoumaker and Sánchez-Páez 2020). In order to draw some potential explanations, we use Bongaarts' proximate determinants framework (Bongaarts 2015) to identify the demographic causes of the stalls. The proximate determinants —-sexual exposure (C_m), contraception (C_c), postpartum insusceptibility (C_i), and abortion (C_a)— are useful for understanding variations in fertility levels because both, they differ among populations and fertility is highly sensitive to changes in them. Hence, changes in fertility should be able to be explained by changes in the proximate determinants. For instance, new evidence confirms that the rates of contraceptive prevalence in SSA countries have not increasead over the last years (Ahmed et al. 2019); therefore, non-decreasing fertility could be expected. Regarding abortion, some studies show the effect it has on fertility by reducing the number of live-birhts (Singh et al. 2018; Sánchez-Páez and Ortega 2019). Patterns of sexual activity have changed over the years in SSA (Westoff 2007). In East and Southern Africa, sexual activity has declined from the early 1990s to 2005, while in West Africa it has increased slightly, if at all, over the same period. As for postpartum insusceptibility, the period of infecundability has been become shorter in recent years in SSA, although it remains higher than in other low- and middle-income regions (Cleland, Shah, and Benova 2015), which explains increases in fertility (Palamuleni 2017; Laelago, Habtu, and Yohannes 2019).

Using contraceptives mean women are willing to avoid pregnancies at that time. However, the opposite case does not always mean that women seek to become pregnant. Some non-users of contraceptives include women who cannot use them even though they intend to do it. Such women fall within the definition of unmet need for contraceptives. In this regard, the fact that contraceptive prevalence has not increased in recent years could be due to two phenomena that are not mutually exclusive. The first of them could be associated with an increase in unmet need for contraceptives. In the case of SSA, about one in four women cannot meet their contraceptive needs (UNFPA 2019); thus, increased fertility would be expected due to unintended childbearing (Casterline, El-Zanaty, and El-Zeini 2003). The other explanation behind the stagnation in contraceptive prevalence might, in turn, be related to fertility preferences. Women in SSA have higher demand for children than women in other low- and middle-income countries (Bongaarts and Casterline 2013). In other words, women in SSA may not be using contraception because they want to get pregnant. In African societies, women want, on average, four children, and this is unlikely to diminish in the short-term (Casterline and Agyei-Mensah 2017). Literature shows the association between the demand for children and fertility at both the aggregate level (e.g., Westoff 1990; Morgan and Rackin 2010) and the individual level (e.g., Schoen et al. 1999); therefore, we are interested in including the demand for children in our analysis.

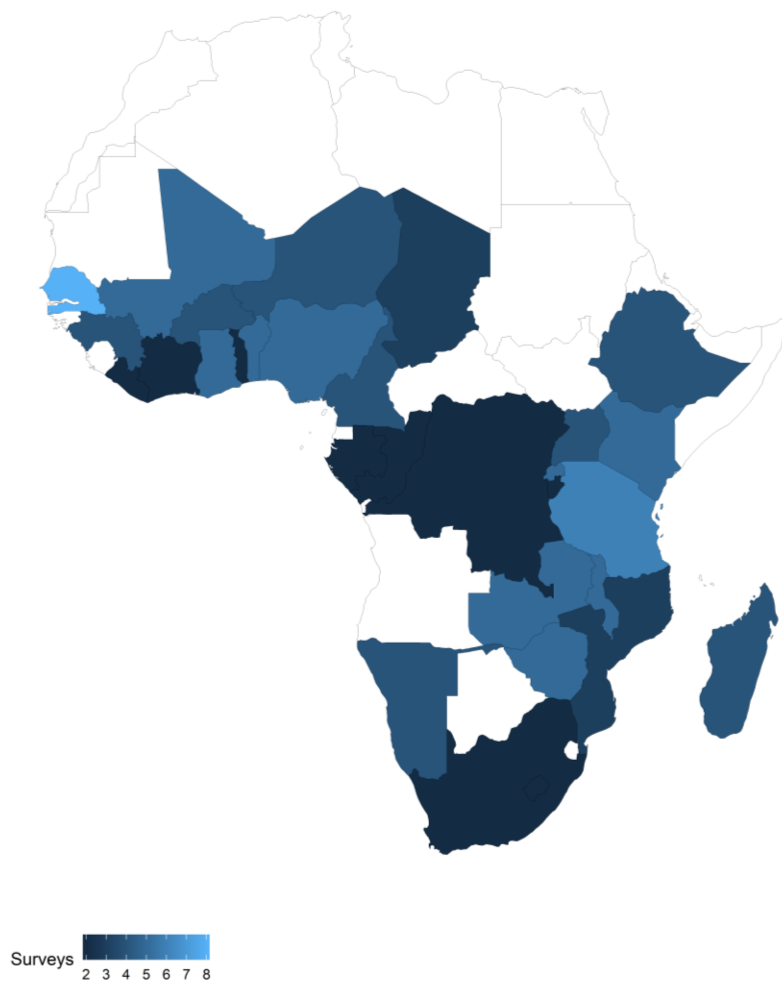
Using an indicator that, at the same time, captures accurately and adequately fertility preferences is neither obvious nor easy. In fact, literature has discussed over the past 30 years which is the best method to measure demand for children. The discussion is summarized in the advantages and disadvantages of using retrospective or prospective information (Casterline and El-Zeini 2007). On the one hand, there are those who argue that retrospective data may be altered by current fertility outcomes, best known as rationalization (Adetunji 1998; Bongaarts 1990). However, most surveys are collected retrospectively and, for better or worse, are the most available for research. On the other hand, the virtue of prospective data is revealing the fertility preference before pregnancy occurs. However, preferences not always remain constant over time. From longitudinal studies or panel data, which because of their structure collect both prospective and retrospective data, it is possible to find changes in preferences before and after pregnancy or birth (e.g., Williams and Abma 2000; Koenig et al. 2006). In other words, women are less likely to declare their children as unintended after birth. Prospective data from panel data should be preferred over retrospective data; nevertheless, it is not widely availabe, especially for national samples in developing countries (Casterline and El-Zeini 2007). At the end, using retrospective or prospective data depends largely on the availability of data and reliability of the survey. We are interested in including the demand for children in our analysis since it is highly correlated to fertility (Casterline and Agyei-Mensah 2017). A study summarizing evidence from longitudinal studies in 28 Asian and African countries finds that women in SSA translate child preferences into birth outcomes (Cleland, Machiyama, and Casterline 2019).

To our knowledge, no studies have analyzed the stalls in the capital cities of SSA countries. We currently know that around two-thirds of the capital cities of SSA have been associated with periods of fertility stalls (Schoumaker and Sánchez-Páez 2020), making them more common than in other urban or rural areas. However, there are no clues on the reasons behind it. Furthermore, this situation becomes more relevant as fertility has stagnated at high values, which is consistent with the high demand for children. We aim to study to what extent the proximate determinants of fertility and demand for children are connected to the periods of stagnation.

2. Data and methods

Our goal is to analyze the role of the proximate determinants and demand for children on the fertility stalls in the capital cities of SSA. For doing so, we use the Demographic and Health Surveys (DHS surveys) since they are the main source of information on fertility in SSA. We need our sample to meet some specific requirements. First, we should be able to identify the capital city or the largest city. In many surveys, and depending on the survey round, two variables need to be combined, for example, `v024` and `v025` or `v101` and `v102`. Second, we need at least two surveys per city since we are interested in analyzing changes over time. Third, every survey should include the information to allow computing the total fertility rate (TFR), proximate determinants, ideal family size (IFS), and unmet need for family planning. Hence, our sample consists of 116 DHS surveys from 30 countries collected between 1990 and 2018 (see Figure 1). All our estimates are for the capital or largest city only, onwards capital cities.

Figure 1. DHS surveys included in the sample.



Regarding the proximate determinants of fertility, we compute them by using the definitions proposed by Bongaarts in the revised model (Bongaarts 2015). An index, between 0 and 1, indicates the fertility-inhibiting effect of each of these proximate determinants. The closer the value is to 1, the smaller the reduction effect. The product of these indexes ($C_m \times C_c \times C_i \times C_a$) indicates the overall fertility-reducing effect of the proximate determinants combined. It is worth noting, we only include three of the proximate determinants of fertility —C_m, C_c, C_i— in our analysis. Although we are aware of its effect on fertility, we leave aside C_a since most surveys do not report information on pregnancies that have not ended in live births. The revised version of the proximate determinants uses sub-regional estimates to compute the abortion index (Bongaarts 2015; Singh et al. 2018). Since all our sample comes from the same sub-regions, computing the index loses interest.

For our purposes, we use IFS as the demand for children. We are aware DHS surveys collect IFS retrospectively and that the reported ideal number of children could be biased upwards, as women are reluctant to provide a lower number than their current number of living children (Casterline and El-Zeini 2007). However, we use IFS for three main reasons. First, perhaps rationalization increases the reported number of desired children; however, determining whether children are unplanned or unwanted is beyond our aim. Second, IFS has the virtue of being a concise expression of the overall demand for children (Casterline and Agyei-Mensah 2017). Third, in DHS surveys women are asked "If you could go back to the time you did not have any children and could choose exactly the number of children to have in your whole life, how many would that be?". Because of the way the question is phrased, it seeks to reduce rationalization bias, which has proven to better capture preferences and be a valid method (Bongaarts 1990). When computing IFS, we exclude women supplying non-numeric responses.

Focusing on our objective, first, we look for the individual contribution of each proximate determinant in variations of fertility over time. We compute the relative change in TFR and analyze which proximate determinant has the most influence on change from the previous (subscript $t-1$) to the current survey (subscript t). Since we are not including C_a in the analysis, the residual includes it and, also, unobserved effects like potential measurement errors:

$$ln(\frac{TFR_t}{TFR_{t-1}}) = ln(\frac{Cm_t}{Cm_{t-1}}) + ln(\frac{Cc_t}{Cc_{t-1}}) + ln(\frac{Ci_t}{Ci_{t-1}}) + residual$$

Second, we are interested in the functional relationship between the proximate determinants, IFS, and TFR. We propose a model to estimate the effect of the determinants of fertility and fertility preferences on fertility trends. We aim to analyze to what extent proximate determinants and the IFS can offset the TFR and, if so, what is the magnitude of the shift. However, we have to consider the unbalanced panel structure of our sample. It includes a different number of surveys for each country, the minimum being 2 and the maximum 8 (see Table A1). Therefore, we use for estimation Linear Mixed Models (LMM) with city-specific random-effect (Galecki and Burzykowski 2013). Using the linear model (LM) drives to inconsistent variance estimates since the variance of the random-effect is different from 0. The exact LR test should be used to verify the need for using LMM instead of LM (Scheipl, Greven, and Kuechenhoff 2008). If the p-value tends to zero, it indicates the need to use LMM estimations. That being said, each observation could be written, in general terms, as:

$$TFR_{it} = \beta' X_{it} + \delta_i + \epsilon_{it}$$

Where TFR_{it} is our variable of interest in capital city i at the time t, β the vector of coefficients, X_{it} the vector of regressors —proximate determinants and IFS—, δ_i the city-specific random-effect, and ϵ_{it} the observation-specific error term.

From a policy perspective, and to better interpret our results, we use the model presented above to propose two sets of scenarios to simulate the potential effect of changes in the proximate determinants and IFS on TFR. The first set establishes as a baseline the first available survey for each capital city. In other words, we address the question "Leaving the rest of variables constant, what if nothing had changed over time?". As a result, we simulate the individual effect of not having faced changes in sexual exposure, contraceptive prevalence, length of postpartum insusceptibility, or the demand for children on TFR of a given survey, to determine whether there is a relationship with fertility stalls. The second set presents the opposite case, this is, we simulate the effect of drastic changes in the proximate determinants and IFS on the TFR. For each case, we intend to place the simulation in such a scenario that it is possible to evaluate the consequences of an extreme situation. The four simulations included in the second set are:

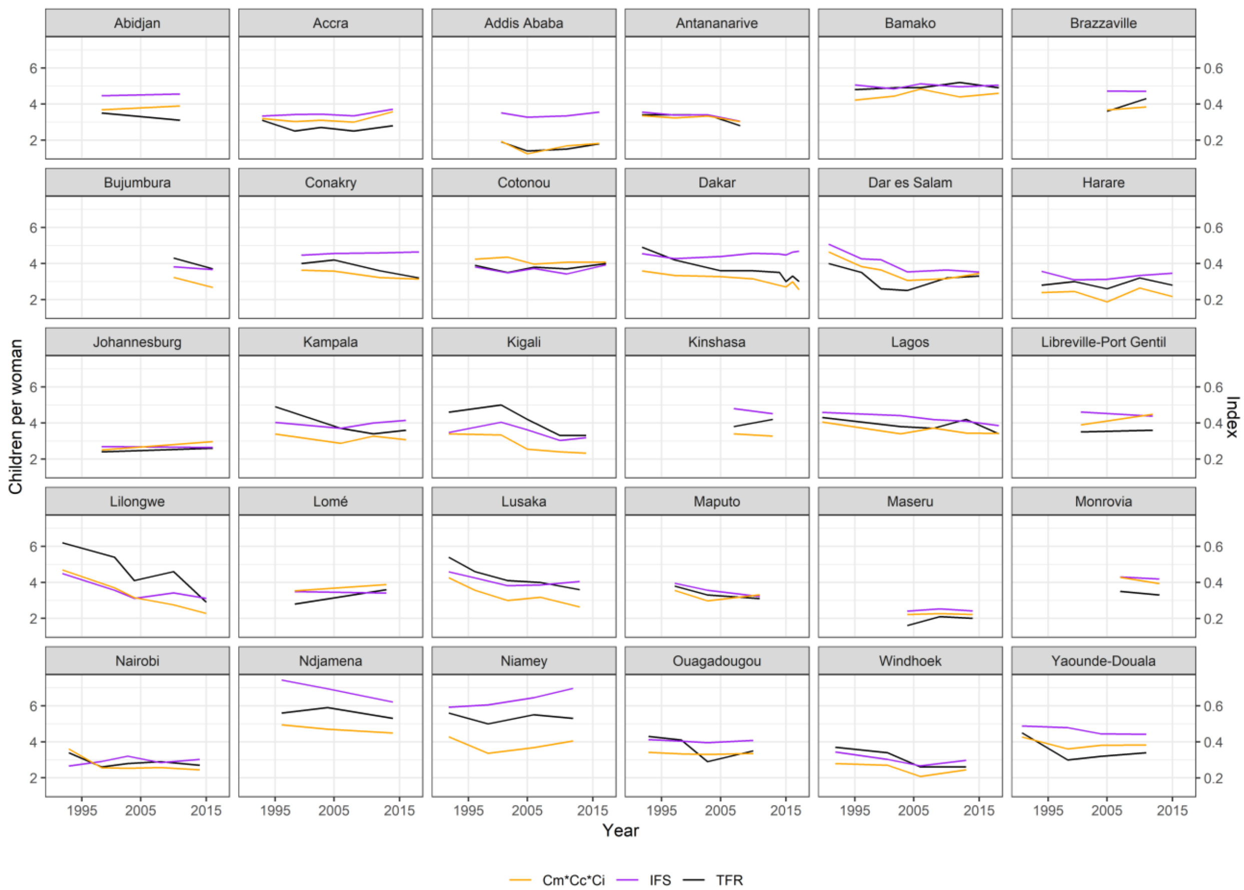
- What would the fertility trends have been if all ever-had-sex women were considered as sexually active? This scenario shows the effect of increasing sexual exposure to its maximum level, where all women who have ever had sex are at risk of becoming pregnant.
- What would the fertility trends have been if women met their demand for contraceptives? This scenario presents a case without unmet need for contraceptives to measure the effect of meeting total demand. In other words, the simulation would show the fertility trend only of those women who wanted to have children since contraceptive prevalence has increased to its maximum level.
- What would the fertility trends have been if only the women who gave birth during the 12 months before the survey could be postpartum insusceptible? This case reduces the length of postpartum insusceptibility to its minimum level to allow women to become pregnant faster after birth.
- What would the fertility trends have been if the IFS had decreased by one child? This scenario shows the marginal effect of decreasing IFS to measure the sensibility of TFR to demand for children.

Multiple scenarios and simulations could be proposed to evaluate the dynamics of the proximate determinants and IFS on TFR; however, our intention is to assess through both sets of scenarios two polarized situations, just to give a quick glance at how the proximate determinants and IFS could be related to periods of fertility stalls.

3. Results

Figure 2 presents the TFR of the 30 cities included in our sample. In general terms, fertility has declined since the 1980s; however, in around 20 capital cities, it has been stalling in recent years. There are cases, such as Brazzaville, Cotonou, Libreville-Port Gentil, Johannesburg, Kinshasa, and Maseru, where TFR is even higher in the last survey than in the first one. There are differences in the levels at which fertility is stalling, for example, Accra, Addis Ababa, Harare, Johannesburg, Maseru, Nairobi, and Windhoek present stalls under 3 children per woman. In Cotonou, Dakar, Dar es Salam, Kampala, Libreville-Port Gentil, Lomé, Maputo, Ougadougou, and Yaounde-Doula the stalls are between 3 and 4 children per woman. Finally, in Bamako, Brazzaville, Kinshasa, Lagos, and Niamey, stalls are over 4 children per woman. Only Addis Ababa and Maseru have a TFR near the replacement level.

Figure 2. Total fertility rate (TFR), ideal family size (IFS) and proximate determinants ($C_m \times C_c \times C_i$) in selected capital cities of sub-Saharan Africa.

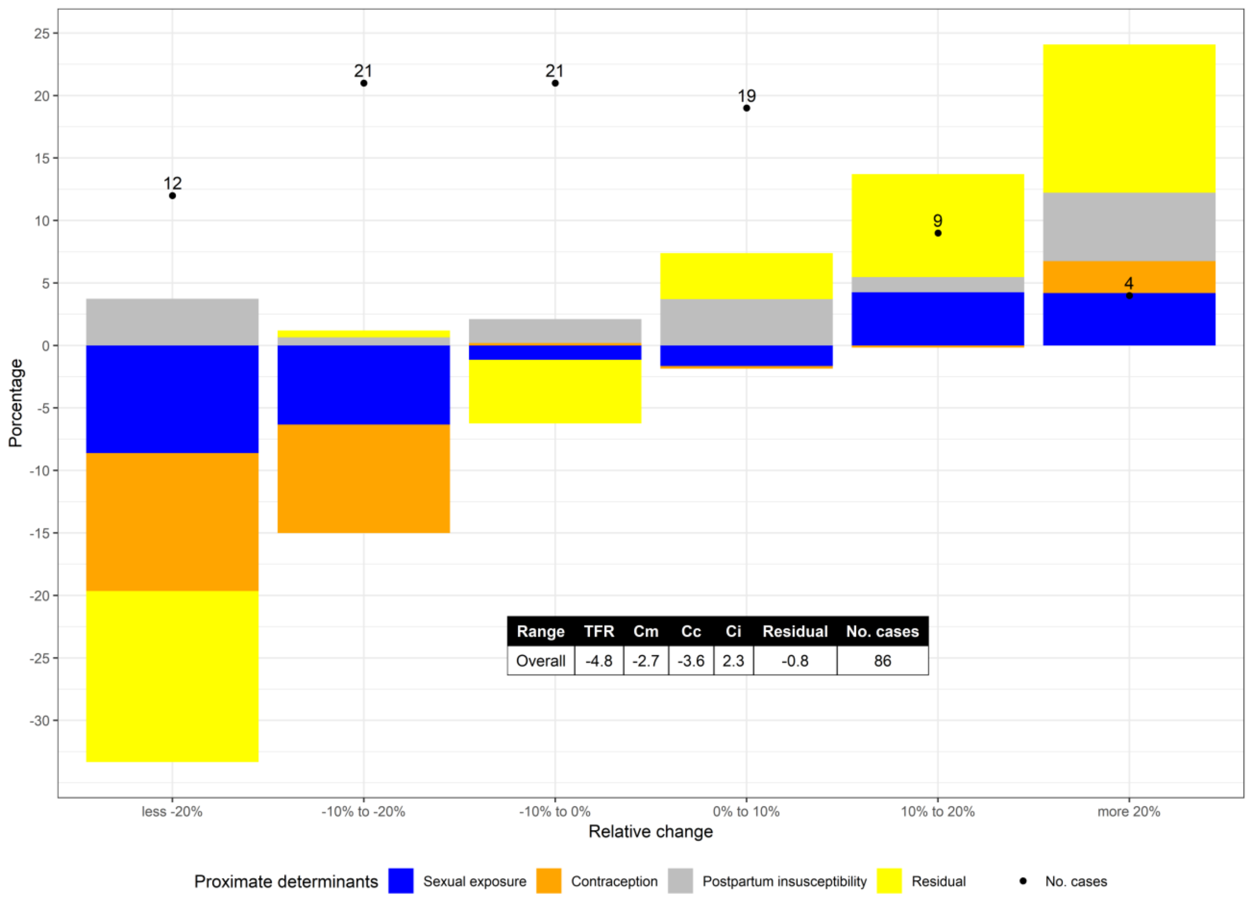


Regarding the product of the proximate determinants, $C_m \times C_c \times C_i$, their interaction indicates the overall fertility-reducing effect of the proximate determinants combined. At a first glance, the trend of the proximate determinants product has stalled in most cities, helping to explain the fertility stagnation in recent years (see Figure 2). From the trends, it is possible to identify three cases. In the first place, there are cities where lower fertility would be expected in the coming years as the interaction of the proximate determinants has continuously decreased, like in Bujumbura, Conakry, Dakar, Kigali, Lilongwe, Lusaka, Monrovia, and Ndjamena. Second, in Abidjan, Accra, Addis Ababa, Antananarivo, Bamako, Brazzaville, Dar es Salam, Johannesburg, Kinshasa, Libreville-Port Gentil, Lomé, Maputo, Niamey, and Windhoek the combination of the proximate determinants would predict higher fertility in recent years than in the previous decade. Third, cities such as Cotonou, Harare, Kampala, Lagos, Maseru, Nairobi, Ouagadougou, and Yaounde-Douala have maintained the same reducing effect, on average, over the last couple of decades. In other words, the product of the three indexes has the same value in the last survey as it did 20 years ago. Also in this case, fertility reductions would not be expected in the coming years. Annex Figure A1 shows the individual trends of the proximate determinants. In most places, C_c has persistently decreased over the years. The reducing effect connected to C_m does not present a common pattern for most cities. Regarding C_i, it is common to virtually all capital cities that postpartum insusceptibility has been losing its reducing effect in the past 30 years.

Fertility preferences contribute to the explanation for the slowdown in the process of fertility reduction. In almost every city the IFS remains about the same as in the early 1990s. On average, since the 2000s the demand for children has stagnated at around 4, which is twice the replacement level (see Figure 2). Women in Abidjan, Addis Ababa, Bamako, Brazzaville, Conakry, Cotonou, Dakar, Johannesburg, Kigali, Libreville-Port Gentil, Maseru, and Ouagadougou want around the same number of children as they did almost three decades ago, most of them over 3.5 children. Cities like Dar es Salam, Kampala, Lilongwe, Lomé, Maputo, Monrovia, and Ndjamena have significantly reduced the IFS. The rest of the cities has small reductions —around 0.5 children— or even increases.

Figure 3 summarizes the relative change of TFR from the pooled sample, explained by variations of the proximate determinants. The relative change shows, on average, a variation in fertility of -4.8% in capital cities since the early 1990s. Most of the decline is explained by reductions in sexual exposure (-2.7%) and increases in contraceptive use (-3.6%). However, at the same time the shortening of the length of postpartum insuceptibility counterbalanced the negative variation of fertility, pushing it upwards (2.3%). Little is left to explain by the residual (-0.8%). A different perspective exists when analyzing the relative change in TFR by range of change. Increases in TFR —i.e., fertility stalls— can be explained depending in the proportion of the increase. For instance, variations of 0% to 10% are related mainly to increases of 3.7% in postpartum insusceptibility, while the rise of 4.2% in sexual exposure accounts for changes of 10% to 20%. In both ranges of change, the contraception index shows small variations, if any, which means that non-increasing contraceptive prevalence contributes to TFR rises, as it is the proximate determinant that most explains negative fertility changes. In all cases, C_i increases, meaning that the reduction in the length of postpartum insusceptibility largely contributes to explain the fertility stalls. On the other hand, in the case of increases over 20% in TFR, the three indexes move upwards significantly. Since we do not control for C_a, the residual category includes abortion and unobserved effects. This category explains most of the variations in TFR above 20%. Perhaps it might be related to measurement errors and/or decreasing abortion. Detailed estimates by city are shown in Table A2 and in Figure A2.

Figure 3. Relative change in TFR and proximate determinants from the previous to the following survey (percentage).



In addition to the contributions to the relative variation of TFR, we estimate the direct effect of the proximate determinants and the ideal number of children on fertility. Table 1 presents the regressions from the pooled data. We include six models, the first three are LMM estimations, and the remaining are linear models. LMM 1 and LM 1 only include the proximate determinants, LMM 2 and LM 2 only the ideal family size, and LMM 3 and LM 3 all the variables. We have used the LR test to test the random-effect restriction and obtained p-values close to zero, meaning the need for using LMM estimations. Regarding the Akaike information criterion (AIC), LMM 3 should be preferred since it has the lowest AIC. C_c and C_m are the proximate determinants with a larger effect on TFR. A 10% increase in any of these indexes would drive to an increase, on average, of 0.44 and 0.40 in TFR, respectively. The same percentage of increase in C_i would lead to increases, on average, of 0.26 in TFR. Regarding IFS, an increase of 1 child in its mean would add, on average, 0.24 to TFR. Figure A3 displays the distribution of the random effect and the error term in the cities of our sample. From both maps, we do not find a geographic correlation and we cannot affirm that a specific subregion has higher or lower variance, except for the random effect in the particular case of some cities in the Atlantic Coast, such as Abidjan, Accra, Conakry, Lomé, and Monrovia. Perhaps further research is needed.

Table 1. Effect of proximate determinants and ideal family size on TFR in the capital cities.

	LMM 1	**LMM 2**	**LMM 3**	**LM 1**	**LM 2**	**LM 3**
Intercept	-5.129***	0.515	-4.944***	-4.956***	0.702**	-3.938***
	(1.024)	(0.383)	(1.007)	(1.028)	(0.288)	(1.013)
C_m	0.044***		0.040***	0.026***		0.022***
	(0.007)		(0.007)	(0.006)		(0.006)
C_c	0.052***		0.044***	0.062***		0.041***
	(0.005)		(0.006)	(0.006)		(0.008)
C_i	0.030***		0.026***	0.037***		0.028**
	(0.010)		(0.010)	(0.011)		(0.011)
IFS		0.767***	0.237**		0.727***	0.328***
		(0.092)	(0.101)		(0.070)	(0.089)
AIC	151.183	206.575	147.805	229.080	249.069	217.731
BIC	167.705	217.590	167.080	242.848	257.329	234.252
Log Likelihood	-69.592	-99.288	-66.902	-109.540	-121.534	-102.865
Num. obs.	116	116	116	116	116	116
Num. groups	30	30	30			
Deviance				44.896	55.209	40.015

From model LMM 3 estimates, we construct the scenarios described in section 2. We present the results from Figure 4 to Figure 7. In all figures, the upper panel corresponds to the first set of scenarios, this is, when the variables remain at the level of the first available survey. The bottom panel shows the second set in which the variables undergo drastic changes. Through the simulations we seek to know if fertility would have been different both in periods of stagnation and in those where there were reductions. Thus, we analyze the results individually for each type of period, so that we can identify if there is a different effect of the variables. The panel on the left shows the results in the stalled periods while the one on the right in the periods of decreasing fertility. The trends are presented from Figure A4 to Figure A7. In these figures, we include, in dashed lines, the predicted —fitted— values. The most salient aspect is that model fit is quite good; this is, the model can reproduce fertility trends in almost all capital cities. Exceptions are Abidjan and Kinshasa; therefore, for these cities we code the results as "unclear". The robustness of the simulations relies on the fact that the fitted values are able to predict the observed data.

Simulations of C_m show fertility, in general terms, would have been higher in most cities under both scenarios, but especially when all ever-had-sex women are considered as sexually active (Figure A4). Overall, fertility stalls would have been greater and more frequent, as shown in Figure 4. In the first case, sexual activity at the level of the first available survey (`simCm1`), the periods of stagnation would have been the same although with variations in the slope of the trend. For instance, in cities such as Accra, Bamako, Johannesburg, Kampala, Libreville-Port Gentil, Lusaka, Nairobi, Niamey and Windhoek, stalled periods would have been more pronounced, which means fertility would have stalled at much higher levels. Only Lilongwe changes the trend towards declining fertility. In the case of non-stalled periods, there is a major effect on fertility. Cities like Accra, Bujumbura, Conakry, Cotonou, Dakar, Kampala, Lagos, Lilongwe, Maputo, Ouagadougou, or Yaounde-Douala would have changed decreasing fertility for plateauing. The second scenario, all ever-had-sex women are sexually active (`simCm2`), have similar results to those of `simCm1` regarding the slope of the trend; however, the level of stagnation is much higher. In other words, those stalled periods identified as more pronounced in `simCm2` are ocurring at higher levels of fertility than those more pronounced periods in `simCm1`. There are cities, such as Dar es Salam and Kigali, which would have faced fertility stalls instead of declining fertility.

Figure 5 displays the simulations of C_c. The effect on fertility trends is different, and opposed, depending on the scenario (see Figure A5). For the first scenario, contraceptive prevalence at the level of first available survey (`simCc1`), in many cities, such as Antananarive, Dakar, Dar es Salam, Harare, Kigali, Libreville-Port Gentil, Lilongwe, Lusaka, Nairobi, Ouagadougou, or Yaounde-Douala, fertility stalls tend to be higher or at least remain at the same levels, which is consistent with increasing contraceptive prevalence over time. The larger effect occurs in periods without stagnation, since cities such as Antananarive, Conakry, Dakar, Dar es Salam, Kigali, Lilongwe, Lusaka, Maputo, Ouagadougou, or Windhoek, would have had fertility stalls rather than decreasing fertility. On the other hand, the second scenario, meeting total demand for contraceptives (`simCc2`), results in lower fertility in all cities. In stalled periods, 8 cities change from plateauing to declining fertility, such as Cotonou, Dakar, Kigali, Lilongwe, Lomé, Lusaka, Ouagadougou, or Yaounde-Douala. Other 10 cities have less pronounced stalls. Only Addis Ababa would have more prnounced fertility stalls trends. In the cases of non-stalled periods, all cities maintain the downward trend in fertility.

Regarding C_i, Figure 6 shows the simulations from both scenarios, length of postpartum insusceptibility at the level of the first available survey (`simCi1`) and only the women who gave birth during the 12 months before the survey could be postpartum insusceptible (`simCi2`). In general terms, fertility tends to be lower in the first scenario and higher in the second (see Figure A6). In the case of `simCi1`, stalled periods mostly remain unchanged or even present declines in the slope. In other words, there still are fertility stalls although they are occurring at lower levels of fertility. In non-stalled periods, fertility tends to decline although cities such as Accra, Antananarive, Conakry, Cotonou, Lagos, or Yaounde-Douala could present stagnation, which is consistent with their increasing trend in postpartum insuscpetibility over time. As for `simCi2`, shortening the length of postpartum insuceptibility would drive to more pronounced stalled periods in Addis Ababa, Bamako, Cotonou, Dakar, Harare, Kampala, Lusaka, Niamey, or Windhoek, which means higher fertility rates. Also, in non-stalled periods, decreasing the length would provoke stalls in Accra, Antananarive, Conakry, Cotonou, Dakar, Kigali, Lagos, Lusaka, Maputo, or Yaounde-Douala.

Figure 4. Effect of changes of C_m on total fertility rate in the capital city.

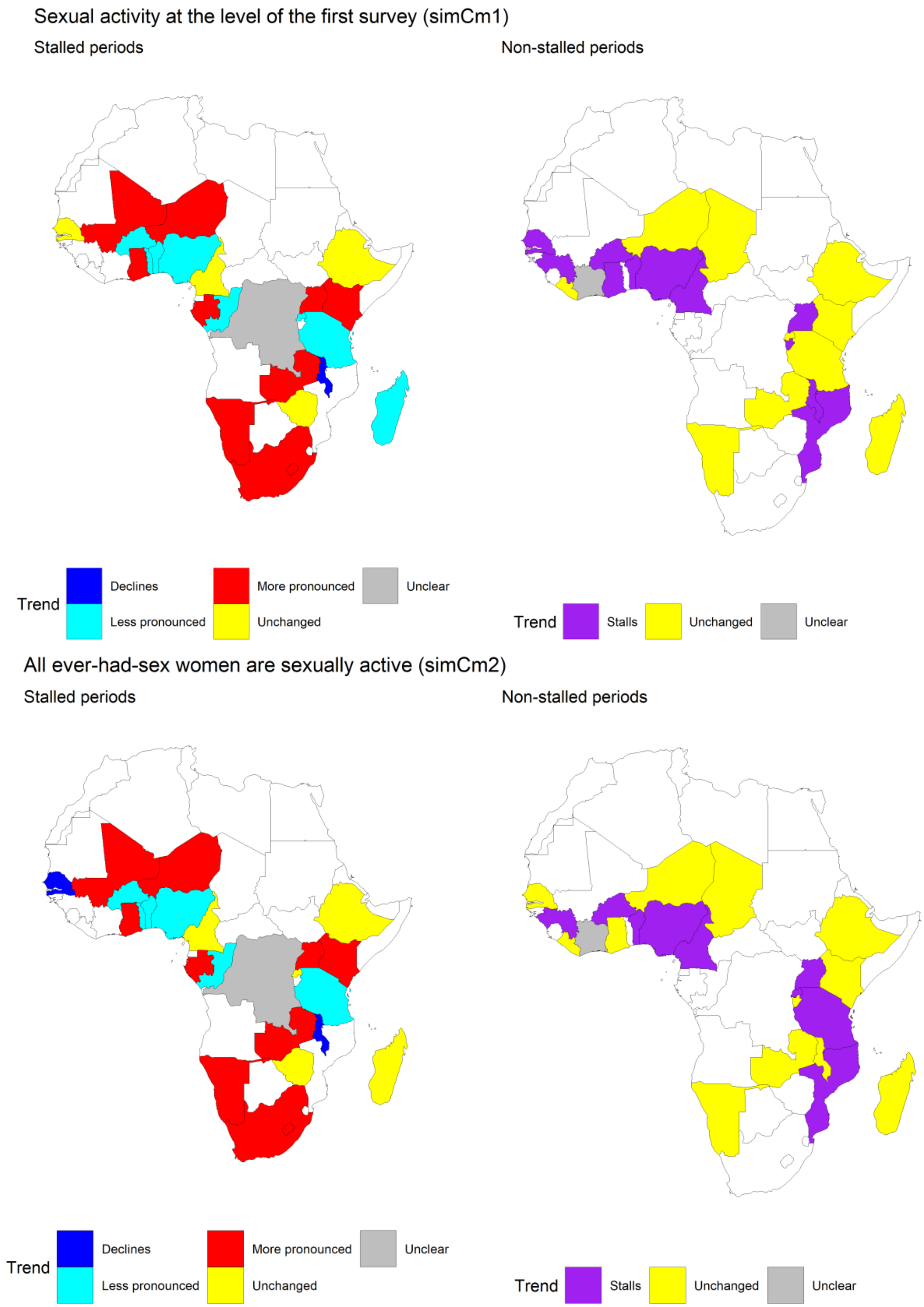
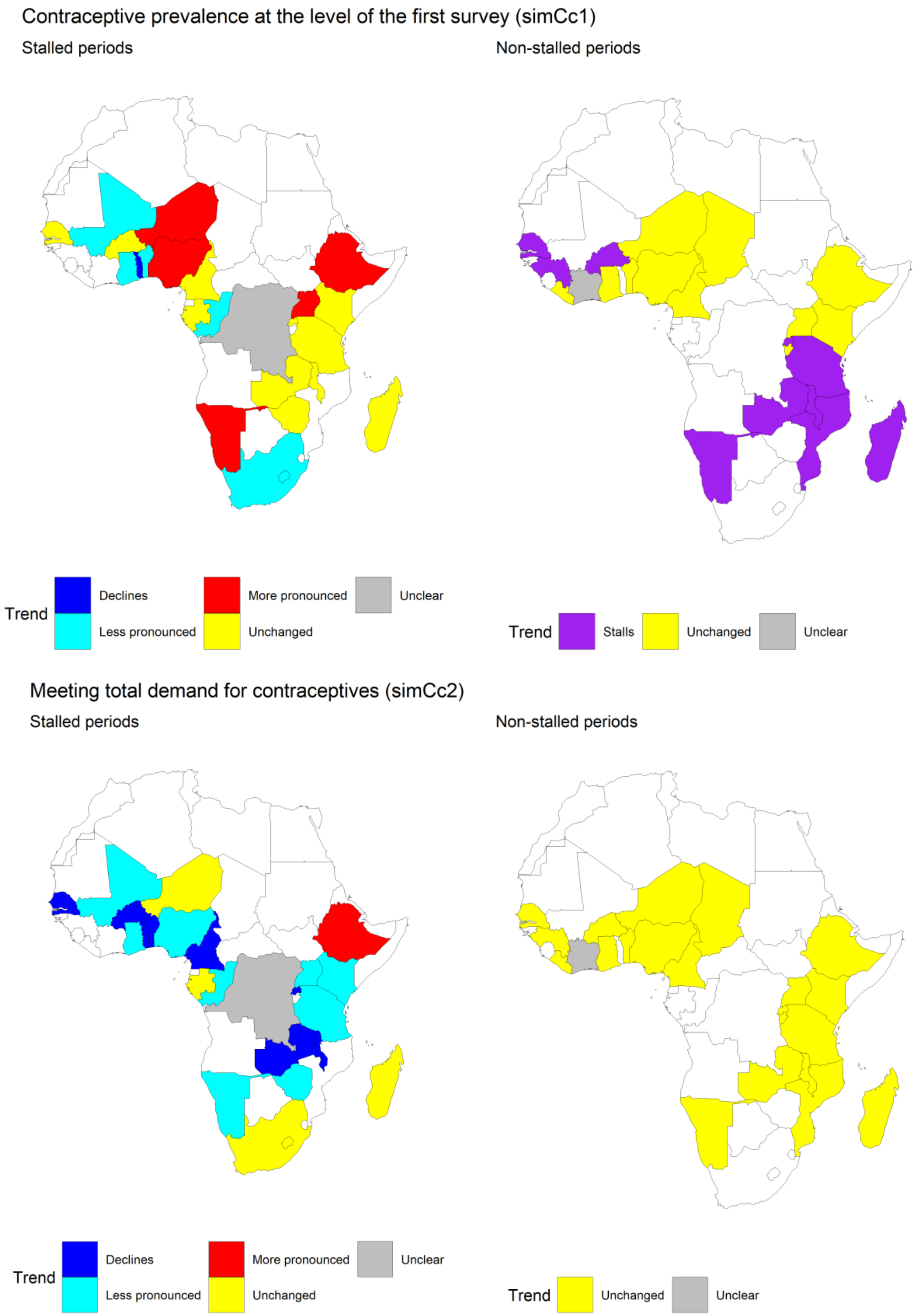


Figure 5. Effect of changes of C_c on total fertility rate in the capital city.



Fertility preferences largely determine family size. Figure 7 displays the results for both scenarios, IFS at the level of the first available survey (`simIFS1`) and the marginal effect of decreasing one child in IFS (`simIFS2`). Demand for children presents small reductions, if any, over time and it contributes to higher fertility and to fertility stalls (see Figure A7). In stalled periods, `simIFS1` shows most cities would tend to have less pronounced stalled periods or remain unchanged, which is consistent with a virtually invariant demand for children over time. Regarding `simIFS2`, less pronounced stalled periods would be expected in Antananarive, Dar es Salam, Harare, Kigali, Lomé, Maseru, Nairobi, Ouagadougou, and Yaounde-Douala, while in Lagos and Lilongwe a decline in fertility could be expected. In non-stalled periods, `simIFS1` predicts stagnation in Accra, Antananarive, Bujumbura, Conakry, Cotonou, Dakar, Dar es Salam, Kigali, Lagos, and Maputo, which is explained by decreases in IFS over time. On the other hand, `simIFS2` shows that no city would change the declining fertility trajectory by decreasing the IFS.

Figure 6. Effect of changes of C_i on total fertility rate in the capital city.

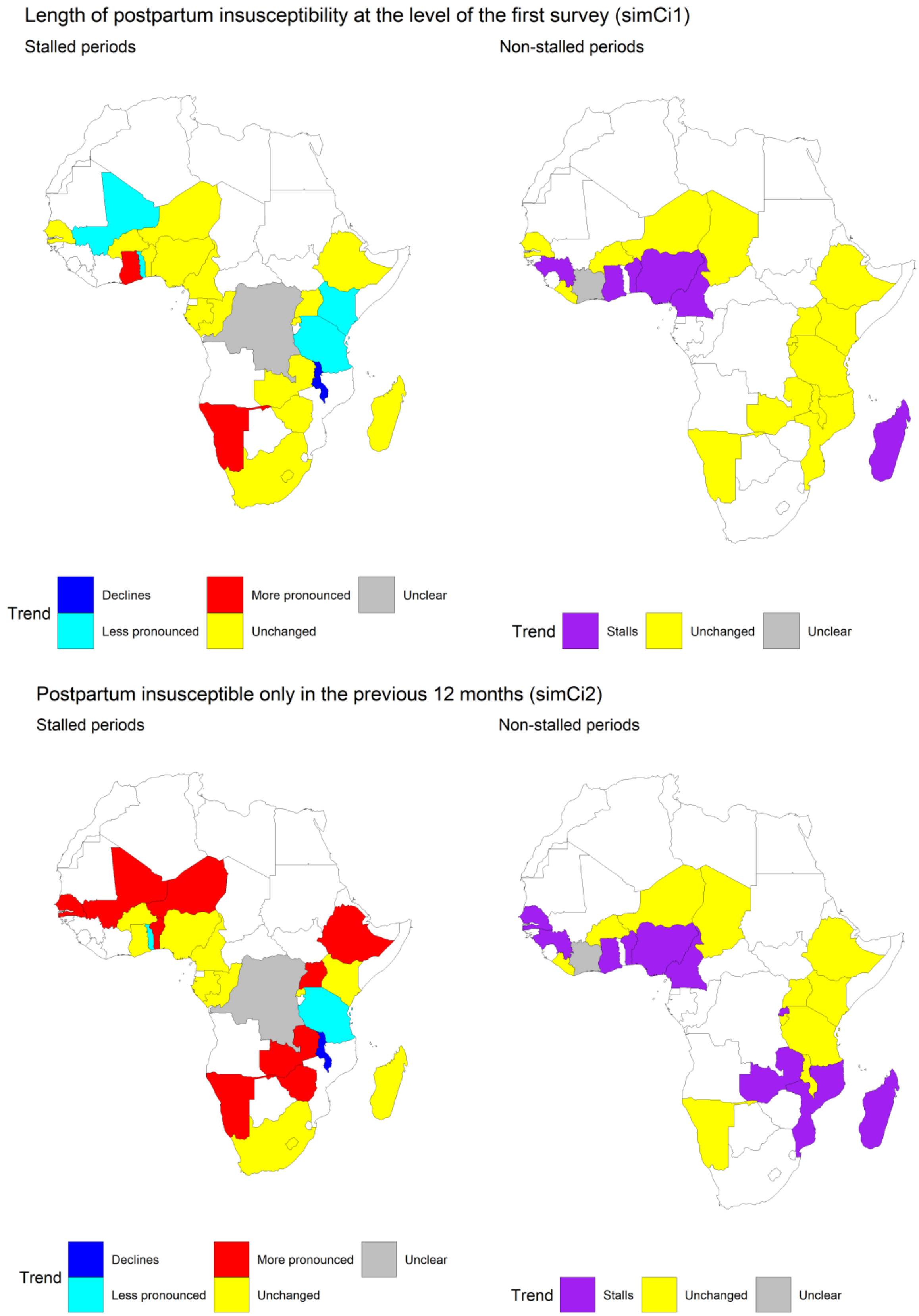
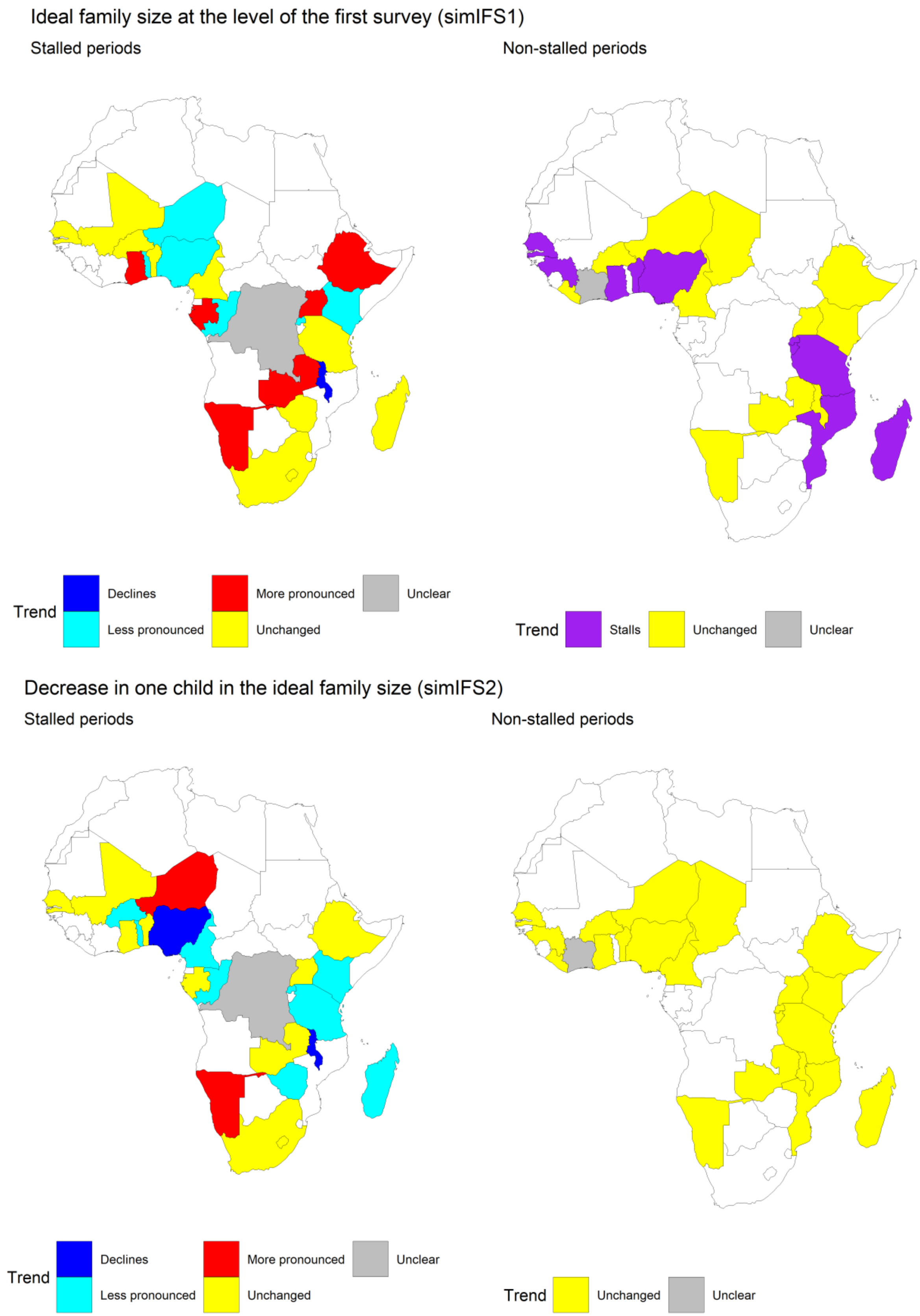


Figure 7. Effect of changes of IFS on total fertility rate in the capital city.



4. Discussion

Fertility stalls in Africa have been first identified in the early 2000s and, since then, the literature has mainly focused at the national level (e.g., Bongaarts 2008; Garenne 2011; Schoumaker 2019). A recent study shows fertility stalls in capital cities are more commonly spread than in other urban areas or rural areas (Schoumaker and Sánchez-Páez 2020). These stalls have been around for roughly 15-20 years in many capital cities, and they seem —at last partly— to result from a high demand for children that has not changed in recent years. And while contraception has increased, it has remained fairly low and its increase has been offset by changes in sexual exposure and postpartum infecundability.

This research is the first providing information on the potential reasons behind the stalls in the capital cities of SSA. We have linked the proximate determinants of fertility and ideal family size to the periods of fertility stalls. We find a clear association between changes in sexual exposure, contraceptive use, postpartum insusceptibility, and the demand for children, and increases in or plateauing of TFR. From our results, variations of TFR can be explained from changes in the proximate determinants of fertility. Small and medium increases in fertility are associated with stagnation of contraceptive use and rises in sexual exposure and postpartum insusceptibility, while large variations are correlated with higher values of the three indexes. On the other hand, reductions in TFR are clearly led by increases in contraceptive use.

Postpartum insusceptibility is the only proximate determinant that pushes TFR upward, regardless of whether fertility is rising or falling. The length of postpartum insusceptibility has diminished over time, which means women can have a subsequent child in a shorter time interval from the last birth. According to our results, and consistent with previous studies (Laelago, Habtu, and Yohannes 2019; Palamuleni 2017), reducing the duration of postpartum insusceptibility increases fertility, and the shorter the length, the greater and more pronounced the periods of fertility stalls. Fertility is sensitive to changes in the term of insusceptibility, and not only in periods of stagnation. Even the declining trend of fertility can be reversed towards plateauing. The effect of reducing amenhorrea and postpartum abstinence need to be considered as relevant from a policy perspective. For the former, breastfeeding should be encouraged not only because it is a natural method of contraception, but also because of the health benefits associated with the newborn. In the case of abstinence, it is important to discuss the use of contraceptives with the obstetrician in the after-birth period to avoid unintended pregnancies. More research is needed to understand the reasons for the decrease in the length of postpartum insusceptibility over time.

Sexual activity is positively related to fertility regardless of whether it has increased or decreased over time, which is consistent with previous results (Westoff 2007). As for the trend of sexual activity, there is no pattern common to all SSA capitals and the level of the predicted fertility from the simulations depends on the observed trajectory. After increasing the share of sexually active women, cities having decreased sexual activity over time are correlated with more pronounced stalled periods and with non-stalled periods converted towards plateauing. In contrast, cities that experience a rise in sexual activity over time increase fertility but not the rate at which it increases, that is, there is an increase in the level but not in the slope of the trend. From a sexual and reproductive health perspective, sexual activity should be accompanied by access to contraceptives to avoid unintended pregnancies. In this respect, it is more achievable to change contraceptive behavior than sexual behavior, especially in adolescents (International Center for Research on Women 2014). From our results, TFR and sexual exposure rise at the same time, which means that in low contraceptive prevalence cities, higher sexual exposure would lead to unintended childbearing. Focusing in contraception is especially important since access and use are associated with women's sexual and reproductive rights. In other words, access and use are not only relevant from the point of view of fertility but also because they constitute in themselves an indicator of gender equity.

In this regard, contraceptive use is highly correlated to fertility. Fertility transitions have started after increasing rates of contraceptive use (Bongaarts 2017); however, it has stalled in recent years in SSA (Ahmed et al. 2019). The plateauing of contraceptive prevalence could mean two things: An increase in unmet need for family planning on the one hand, or that contraception is no longer demanded on the other. In the first case, the effect of meeting total demand translates into reductions in fertility. From our results, stalled periods in almost every city would not have been so if there was no unmet need for contraceptives. Fertility levels would be halved in virtually all SSA capitals. Moreover, the increase in contraceptive prevalence since the early 1990s has already contributed to the decline in TFR. The simulations show that if this had not been the case, the non-stalled periods would have been transformed into stalled periods in several of the cities, meaning higher TFR. Despite the increase of contraceptive use in the last three decades, it still remains at lower rates than in other low- and middle-income countries, and with no signs of a sharp increase in the short-term. Family planning programs are essential for knowledge, access and use of contraceptives to prevent unwanted pregnancies.

The second case is related to the demand for children. Data confirms the preference for medium and large families in SSA capitals. In fact, not only do women want large families, but they are actually having them (Cleland, Machiyama, and Casterline 2019). Therefore, the demand for children shows slight reductions, if any, over time. Ideal family size is highly correlated to fertility and small variations could drive to significant increases in it. From our results, cities where ideal family size has decreased over time present reductions in fertility. In the event that those cities have not had such reductions in ideal family size, periods of declining fertility could have been replaced by periods of stagnation. The marginal effect of decreasing ideal family size drives to lower fertility rates in all SSA capitals. In stalled periods, if demand for children had been lower by one child, the slope of the fertility trend would also have been lower. In other words, in many citied fertility would have declined in level and at a faster pace. Demand for children in SSA remains high, even higher than in other developing regions (Bongaarts and Casterline 2013). Moreover, it is unlikely to diminish it in the short-term (Casterline and Agyei-Mensah 2017). We are interested in further research into the reasons behind the high demand for children in SSA.

Our limitations include, first, the use of retrospective information to estimate the demand for children. There are some concerns since some authors consider prospective information is more reliable (Casterline and El-Zeini 2007). Retrospective preferences are subject to problems of rationalization and non-numerical responses (e.g., "Up to God"). However, we use it since the stated ideal number of children has the virtue of being a concise expression of the overall demand for children (Casterline and El-Zeini 2007). Also, because women in SSA countries usually have the number of children they want, or even more (Cleland, Machiyama, and Casterline 2019). Second, we are not including abortion in the analysis since not all DHS surveys have information about pregnancies not ending in live births. We are aware that part of the changes in TFR could be related to abortion; however, results show that the three indexes account for most part of variations.

References

Adetunji, J.A. (1998). *Unintended Childbearing in Developing Countries: Levels, Trends, and Determinants. DHS*. Calverton: Macro International, DHS Analytical Reports No. 8. https://dhsprogram.com/pubs/pdf/AR8/AR8.pdf.

Ahmed, S., Choi, Y., Rimon, J.G., Alzouma, S., Gichangi, P., Guiella, G., Kayembe, P., Kibira, S.P., Makumbi, F., OlaOlorun, F., Omoluabi, E., Otupiri, E., Oumarou, S., Seme, A., Shiferaw, S., Anglewicz, P., Radloff, S., and Tsui, A. (2019). Trends in contraceptive prevalence rates in sub-Saharan Africa since the 2012 London Summit on Family Planning: Results from repeated cross-sectional surveys. *Lancet Global Health* 7(7):904–911. doi:10.1016/S2214-109X(19)30200-1.

Blanc, A.K. and Gray, S. (2002). Greater than expected fertility decline in Ghana: An examination of the evidence. *Journal of Biosocial Science* 34(4):475–495. doi:10.1017/s0021932002004753.

Bocquier, P. and Schoumaker, B. (2018). *The Demographic Transition in Sub-Saharan Africa and the Role of Urban Areas in This Transition*. Louvain-la-Neuve: Centre de recherche en démographie – DEMO; Université Catholique de Louvain.

Bongaarts, J. (2006). The causes of stalling fertility transitions. *Studies in Family Planning* 37(1):1–16. doi:10.1111/j.1728-4465.2006.00079.x.

Bongaarts, J. (2008). Fertility transitions in developing countries: Progress or stagnation? *Studies in Family Planning* 39(2):105–110. doi:10.1111/j.1728-4465.2008.00157.x.

Bongaarts, J. (2015). Modeling the fertility impact of the proximate determinants: Time for a tune-up. *Demographic Research* 33(19):535–560. doi:10.4054/DemRes.2015.33.19.

Bongaarts, J. (1990). The measurement of wanted fertility. *Population and Development Review* 16(3):487–506. doi:10.2307/1972833.

Bongaarts, J. (2017). The effect of contraception on fertility: Is sub-Saharan Africa different? *Demographic Research* 37(6):129–146. doi:10.4054/DemRes.2017.37.6.

Bongaarts, J. and Casterline, J.B. (2013). Fertility transition: Is sub-Saharan Africa different? *Population and Development Review* 38(Suppl. 1):153–168. doi:10.1111/j.1728-4457.2013.00557.x.

Casterline, J.B. and Agyei-Mensah, S. (2017). Fertility desires and the course of fertility decline in sub-Saharan Africa. *Population and Development Review* 43(S1):84–111. doi:10.1111/padr.12030.

Casterline, J.B., El-Zanaty, F., and El-Zeini, laila O. (2003). Unmet need and unintended fertility: Longitudinal evidence from Upper Egypt. *International Family Planning Perspectives* 29(4):158–166. doi:10.2307/3181044.

Casterline, J.B. and El-Zeini, L.O. (2007). The estimation of unwanted fertility. *Demography* 44(4):729–745. doi:10.1353/dem.2007.0043.

Cleland, J., Machiyama, K., and Casterline, J.B. (2019). Fertility preferences and subsequent childbearing in Africa and Asia: A synthesis of evidence from longitudinal studies in 28 populations. *Population Studies*:1–21. doi:10.1080/00324728.2019.1672880.

Cleland, J., Shah, I.H., and Benova, L. (2015). A fresh look at the level of unmet need for family planning in the postpartum period, its causes and program implications. *International Perspectives on Sexual and Reproductive Health* 41(3):155–162. doi:10.1363/intsexrephea.41.3.155.

Ezeh, A.C., Mberu, B.U., and Emina, J.O. (2009). Stall in fertility decline in Eastern African countries: Regional analysis of patterns, determinants and implications. *Phil. Trans. R. Soc. B.* 364(1532):2991–3007. doi:10.1098/rstb.2009.0166.

Galecki, A. and Burzykowski, T. (2013). *Linear Mixed-Effects Models Using R*. New York: Springer.

Garenne, M. (2008). Situations of fertility stall in sub-Saharan Africa. *African Population Studies* 23(2):173–188. doi:10.11564/23-2-319.

Garenne, M. and Joseph, V. (2002). The timing of the fertility transition in sub-Saharan Africa. *World Development* 30(10):1835–1843. http://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_7/sous_copyright/010032130.pdf.

Garenne, M.L. (2011). Testing for fertility stalls in demographic and health surveys. *Population Health Metrics* 9:59. doi:10.1186/1478-7954-9-59.

International Center for Research on Women (2014). *Understanding the Adolescent Family Planning Evidence Base*. Washington D.C.: International Center for Research on Women (ICRW); ICRW. https://www.icrw.org/wp-content/uploads/2016/10/FINAL-Understanding-the-Adolescent-Family-Planning-Evidence-Base-7.30.pdf.

Kinfu, Y. (2000). Below-replacement fertility in tropical Africa? Some evidence from Addis Ababa. *Journal of the Australian Population Association* 17(1):63–82. doi:10.1007/BF03029448.

Koenig, M.A., Acharya, R., Singh, S., and Roy, T.K. (2006). Do current measurement approaches underestimate levels of unwanted childbearing? Evidence from rural India. *Population Studies* 60(3):243–256. doi:10.1080/00324720600895819.

Laelago, T., Habtu, Y., and Yohannes, S. (2019). Proximate determinants of fertility in Ethiopia; an application of revised Bongaarts model. *Reproductive Health* 16(13):1–9. doi:10.1186/s12978-019-0677-x.

Lerch, M. (2019). Fertility decline in urban and rural areas of developing countries. *Population and Development Review* 45(2):301–320. doi:10.1111/padr.12220.

Morgan, S.P. and Rackin, H. (2010). The correspondence between fertility intentions andbehavior in the United States. *Population and Development Review* 36(1):91–118. doi:10.1111/j.1728-4457.2010.00319.x.

Palamuleni, M.E. (2017). Determinants of fertility decline in Namibia: An analysis of the Proximate Determinants. *Bangladesh e-Journal of Sociology* 14(2):41–63. http://www.bangladeshsociology.org/Determinants14.2.pdf.

Sánchez-Páez, D.A. and Ortega, J.A. (2019). Reported patterns of pregnancy termination from Demographic and Health Surveys. *PLoS ONE* 14(8):e0221178. doi:10.1371/journal.pone.0221178.

Scheipl, F., Greven, S., and Kuechenhoff, H. (2008). Size and power of tests for a zero random effect variance or polynomial regression in additive and linear mixed models. *Computational Statistics & Data Analysis* 52(7):3283–3299. doi:10.1016/j.csda.2007.10.022.

Schoen, R., Astone, N.M., Kim, Y.J., Nathanson, C.A., and Fields, J.M. (1999). Do fertility intentions affect fertility behavior? *Journal of Marriage and Family* 61(3):790–799. doi:10.2307/353578.

Schoumaker, B. (2019). Stalls in fertility transitions in Sub-Saharan Africa: Revisiting the evidence. *Studies in Family Planning* 50(3):257–278. doi:10.1111/sifp.12098.

Schoumaker, B. and Sánchez-Páez, D.A. (2020). *Identifying Fertility Stalls by Place of Residence in Sub-Saharan Africa*. Louvain-la-Neuve: Centre de recherche en démographie – DEMO; Université Catholique de Louvain.

Shapiro, D. and Gebreselassie, T. (2008). Fertility transition in sub-Saharan Africa: Falling and stalling. *African Population Studies* 23(1):3–23. doi:10.11564/23-1-310.

Shapiro, D. and Tambashe, B.O. (2002). Fertility transition in urban and rural areas of sub-Saharan Africa: Preliminary evidence of a three-stage process. *Journal of Africa Policy Studies* 8(2):103–127.

Singh, S., Remez, L., Sedgh, G., Kwok, L., and Onda, T. (2018). *Abortion Worldwide 2017: Uneven Progress and Unequal Access*. New York: Guttmacher Institute. https://www.guttmacher.org/sites/default/files/report_pdf/abortion-worldwide-2017.pdf.

UNFPA (2019). World Population Dashboard [electronic resource]. New York: United Nations Population Fund. https://www.unfpa.org/data/world-population-dashboard.

Westoff, C.F. (2007). Recent trends in rates of sexual activity in sub-Saharan Africa. *Journal of Biosocial Science* 39(6):895–904. doi:10.1017/S0021932007001848.

Westoff, C.F. (1990). Reproductive intentions and fertility rates. *International Family Planning Perspectives* 16(3):84–89. doi:10.2307/2133304.

Westoff, C.F. and Cross, A.R. (2006). *The Stall in the Fertility Transition in Kenya. DHS Analytical Studies No. 9*. Calverton, Maryland, USA: ORC Macro.: pages. http://dhsprogram.com/pubs/pdf/AS9/AS9.pdf.

Williams, L. and Abma, J. (2000). Birth wantedness reports: A look forward and a look back. *Social Biology* 47(3–4):147–163. doi:10.1080/19485565.2000.9989016.

Annex

Table A1. List of capital cities included in the sample.

Capital	Country	Surveys	Women 15-49	Capital	Country	Surveys	Women 15-49
Abidjan	Cote d'Ivoire	2	3,207	Kinshasa	Congo D.R.	2	3,830
Accra	Ghana	5	4,576	Lagos	Nigeria	5	8,006
Addis Ababa	Ethiopia	4	3,259	Libreville-Port Gentil	Gabon	2	8,499
Antananarive	Madagascar	4	3,365	Lilongwe	Malawi	5	4,450
Bamako	Mali	5	8,807	Lomé	Togo	2	4,685
Brazzaville	Congo	2	6,326	Lusaka	Zambia	5	7,245
Bujumbura	Burundi	2	1,987	Maputo	Mozambique	3	2,516
Conakry	Guinea	4	6,225	Maseru	Lesotho	3	3,249
Cotonou	Benin	5	7,074	Monrovia	Liberia	2	5,825
Dakar	Senegal	8	22,252	Nairobi	Kenya	5	6,609
Dar es Salam	Tanzania	6	4,643	Ndjamena	Chad	3	2,840
Harare	Zimbabwe	5	7,024	Niamey	Niger	4	2,842
Johannesburg	South Africa	2	4,707	Ouagadougou	Burkina Faso	4	4,978
Kampala	Uganda	4	3,088	Windhoek	Namibia	4	6,219
Kigali	Rwanda	5	4,417	Yaounde-Douala	Cameroon	4	7,143

Figure A1. Proximate determinants computed according to Bongaarts' model definitions.

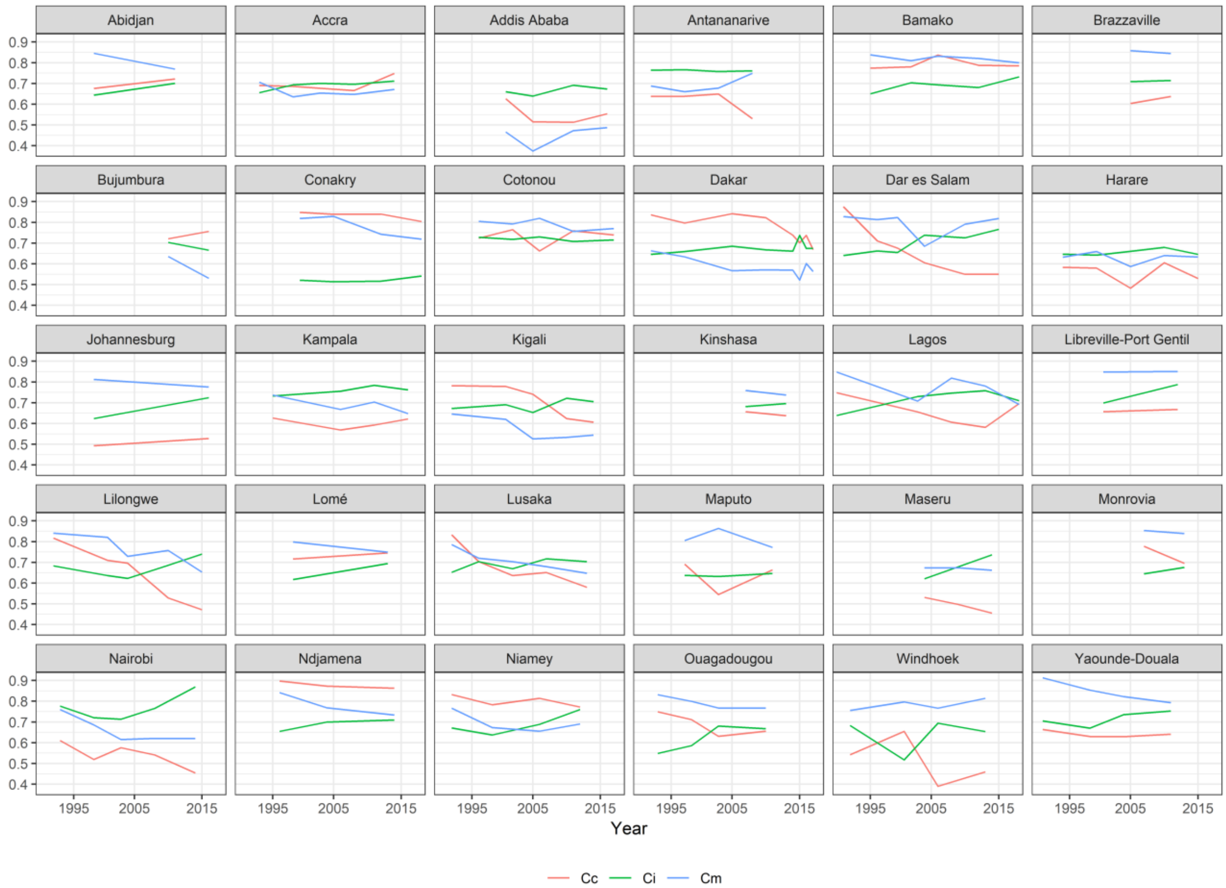


Figure A2. Relative change in TFR and proximate determinants from the previous to the following survey by capital city.

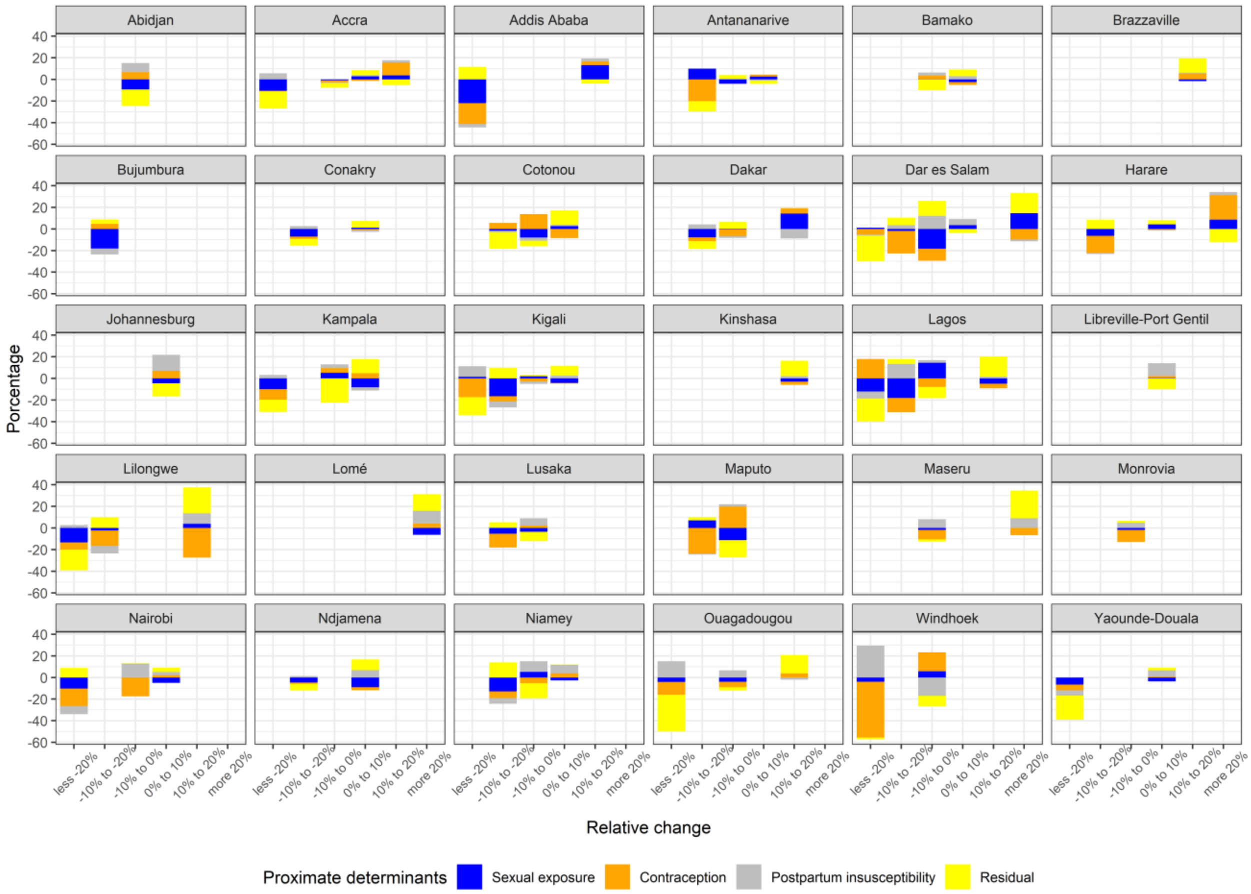


Table A2. Relative change of TFR and the proximate determinants by capital city (percentage).

Year	TFR	C_m	C_c	C_i	Residual
Abidjan – Cote d'Ivoire					
1998					
2011	-9.5	-9.4	6.6	8.4	-15.2
Accra – Ghana					
1993					
1998	-21.2	-10.5	-0.6	5.6	-15.7
2003	7.2	2.7	-1.4	1.1	4.7
2008	-7.6	-1.0	-1.6	-0.8	-4.3
2014	12.4	3.7	11.7	2.3	-5.4
Addis Ababa – Ethiopia					
2000					
2005	-32.9	-21.9	-19.4	-3.2	11.7
2011	12.0	23.3	-0.5	7.8	-18.6
2016	18.7	2.9	7.6	-2.7	10.8
Antananarive – Madagascar					
1992					
1997	0.0	-4.1	0.1	0.4	3.6
2003	0.1	2.7	1.7	-1.2	-3.0
2008	-19.3	9.9	-20.2	0.5	-9.5
Bamako – Mali					
1995					
2001	1.9	-3.5	0.8	7.9	-3.4
2006	-1.0	2.7	7.1	-1.4	-9.4
2012	6.2	-1.4	-6.1	-1.9	15.6
2018	-6.2	-2.5	-0.3	7.2	-10.6
Brazzaville – Congo					
2005					
2011	17.8	-1.7	5.4	0.8	13.3
Bujumbura – Burundi					
2010					
2016	-14.9	-18.1	4.7	-5.5	4.0
Conakry – Guinea					

1999					
2005	4.8	1.2	-1.1	-1.5	6.2
2012	-15.4	-11.0	0.1	0.5	-5.0
2018	-10.5	-3.2	-4.3	4.8	-7.7
Cotonou – Benin					
1996					
2001	-12.8	-1.6	5.5	-1.4	-15.3
2006	7.8	3.4	-14.4	1.6	17.2
2011	-2.3	-8.0	13.6	-3.0	-5.1
2017	9.3	1.7	-2.7	1.0	9.3
Dakar – Senegal					
1992					
1997	-15.3	-4.6	-4.8	2.1	-8.0
2005	-14.7	-11.0	5.6	3.7	-12.9
2010	-0.7	0.7	-2.4	-2.5	3.5
2014	-2.9	-0.3	-10.8	-1.0	9.2
2015	-16.1	-8.8	-5.2	10.9	-13.0
2016	10.3	14.2	5.0	-8.9	0.1
2017	-11.2	-6.6	-9.7	0.0	5.2
Dar es Salam – Tanzania					
1991					
1996	-12.1	-1.9	-20.8	3.4	7.1
1999	-28.6	1.2	-5.1	-1.2	-23.6
2004	-3.4	-18.4	-10.9	12.0	13.9
2010	21.7	14.5	-9.8	-1.7	18.8
2015	5.2	3.4	0.1	5.5	-3.8
Harare – Zimbabwe					
1994					
1999	6.5	4.2	-0.7	-0.8	3.8
2005	-15.7	-11.5	-18.3	2.9	11.2
2010	21.8	8.6	22.7	2.9	-12.4
2015	-13.6	-1.1	-13.4	-5.1	6.1
Johannesburg – South Africa					
1998					
2016	5.2	-4.6	6.9	14.9	-12.0
Kampala – Uganda					
1995					

2006	-27.8	-9.9	-9.7	3.2	-11.4
2011	-9.3	5.2	4.3	3.6	-22.4
2016	6.8	-8.3	4.8	-2.9	13.2
Kigali – Rwanda					
1992					
2000	7.0	-4.1	-0.6	2.6	9.0
2005	-17.1	-16.4	-4.9	-5.5	9.8
2010	-22.9	1.4	-17.3	9.9	-16.9
2014	-1.9	2.0	-2.8	-2.3	1.2
Kinshasa – Congo D.R.					
2007					
2013	10.5	-3.0	-2.9	2.2	14.3
Lagos – Nigeria					
1990					
2003	-13.1	-18.0	-13.1	13.4	4.6
2008	-1.3	14.5	-7.8	2.3	-10.3
2013	11.1	-4.9	-4.2	1.6	18.6
2018	-21.8	-12.0	18.0	-6.6	-21.1
Libreville-Port Gentil – Gabon					
2000					
2012	4.1	0.4	1.8	12.0	-10.0
Lilongwe – Malawi					
1992					
2000	-13.8	-2.4	-14.1	-7.1	9.8
2004	-27.0	-11.9	-2.0	-2.1	-11.0
2010	10.1	3.9	-27.4	9.7	24.0
2015	-45.9	-14.9	-11.4	7.6	-27.2
Lomé – Togo					
1998					
2013	24.9	-6.3	4.0	11.8	15.4
Lusaka – Zambia					
1992					
1996	-15.7	-8.8	-16.8	7.6	2.3
2001	-11.7	-2.3	-10.0	-4.9	5.5
2007	-3.1	-3.5	2.2	6.8	-8.7
2013	-11.2	-4.8	-11.6	-1.9	7.0

Maputo – Mozambique					
1997					
2003	-14.8	7.0	-23.7	-0.8	2.7
2011	-5.2	-11.3	19.8	2.2	-15.9
Maseru – Lesotho					
2004					
2009	27.9	0.0	-6.7	9.0	25.6
2014	-4.6	-1.7	-8.9	8.1	-2.1
Monrovia – Liberia					
2007					
2013	-6.4	-1.8	-11.3	4.7	1.9
Nairobi – Kenya					
1993					
1998	-25.2	-10.3	-16.2	-7.6	8.8
2003	4.0	-10.8	10.2	-0.9	5.5
2008	4.0	0.8	-6.2	7.0	2.4
2014	-4.2	-0.1	-17.4	12.7	0.5
Ndjamena – Chad					
1996					
2004	5.0	-9.1	-2.8	6.7	10.1
2014	-10.7	-4.7	-1.2	1.3	-6.2
Niamey – Niger					
1992					
1998	-10.2	-12.9	-6.1	-5.3	14.0
2006	9.3	-2.7	3.9	7.8	0.3
2012	-4.1	5.2	-5.3	9.9	-13.9
Ouagadougou – Burkina Faso					
1993					
1998	-5.6	-4.0	-5.1	6.5	-3.0
2003	-34.9	-4.1	-12.0	14.9	-33.8
2010	18.8	-0.2	3.7	-1.9	17.1
Windhoek – Namibia					
1992					
2000	-6.8	5.4	18.8	-27.7	-3.2
2006	-27.9	-3.9	-51.6	29.4	-1.7

2013	-0.4	6.0	16.2	-6.0	-16.6
Yaounde-Douala – Cameroon					
1991					
1998	-39.1	-6.7	-5.2	-5.0	-22.2
2004	7.1	-3.7	-0.1	9.3	1.6
2011	3.7	-3.6	1.8	2.3	3.1

Figure A3. Maps of estimated random effects and residuals in model LMM 3.

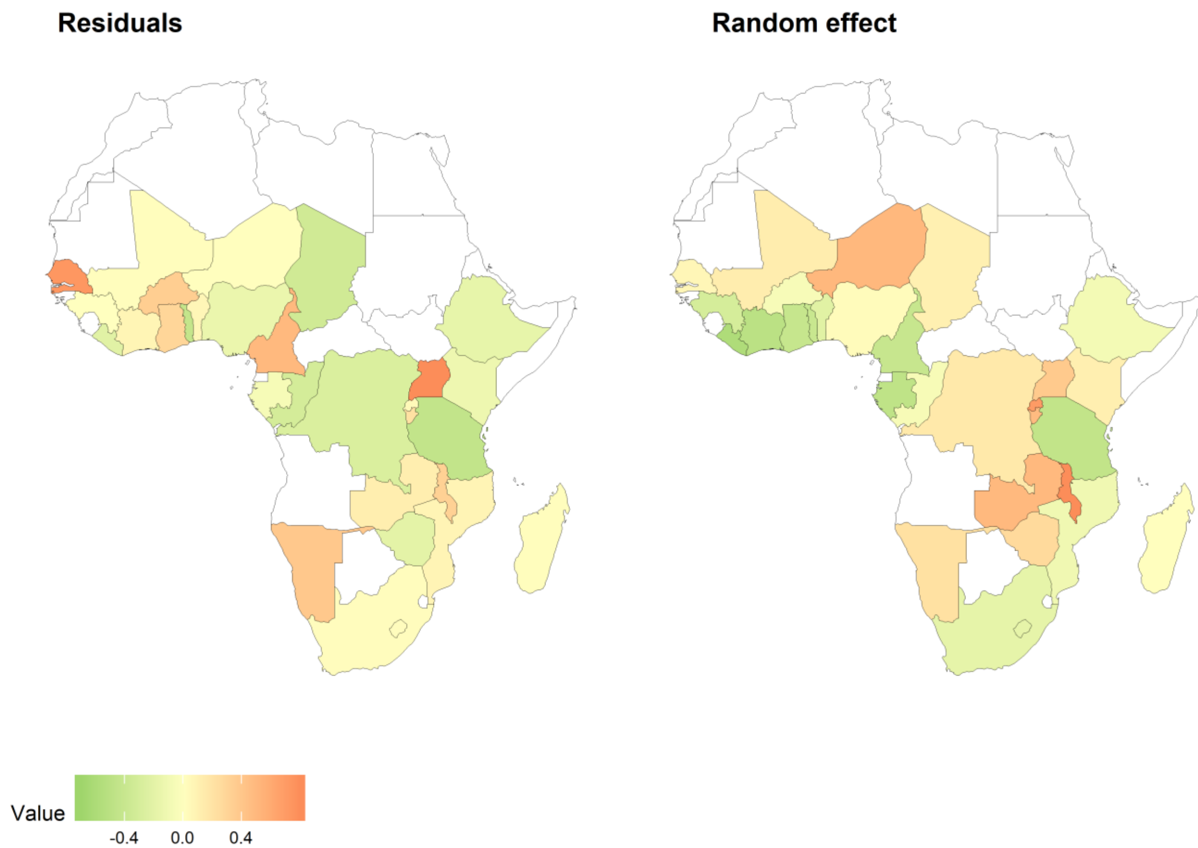


Figure A4. Effect of changes of C_m on total fertility rate.

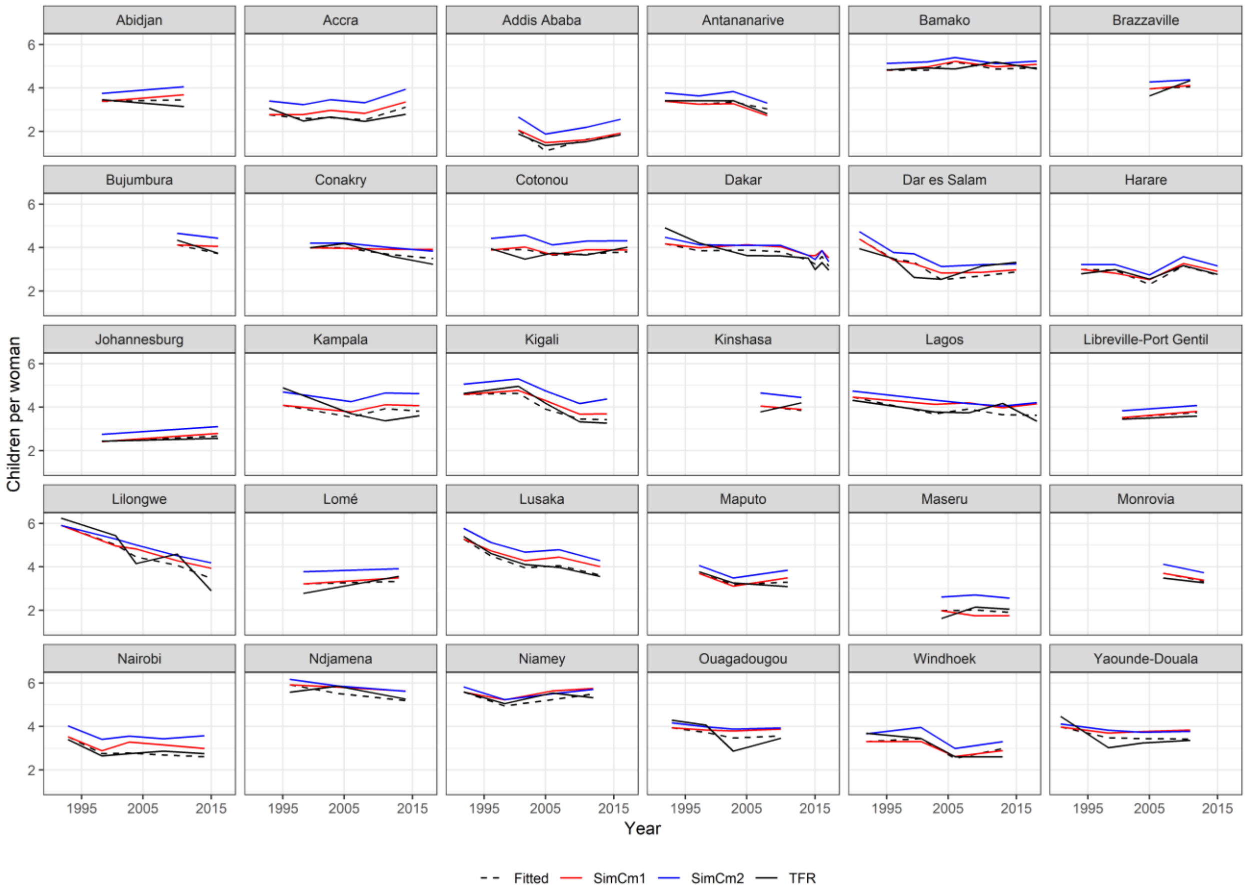


Figure A5. Effect of changes of C_c on total fertility rate.

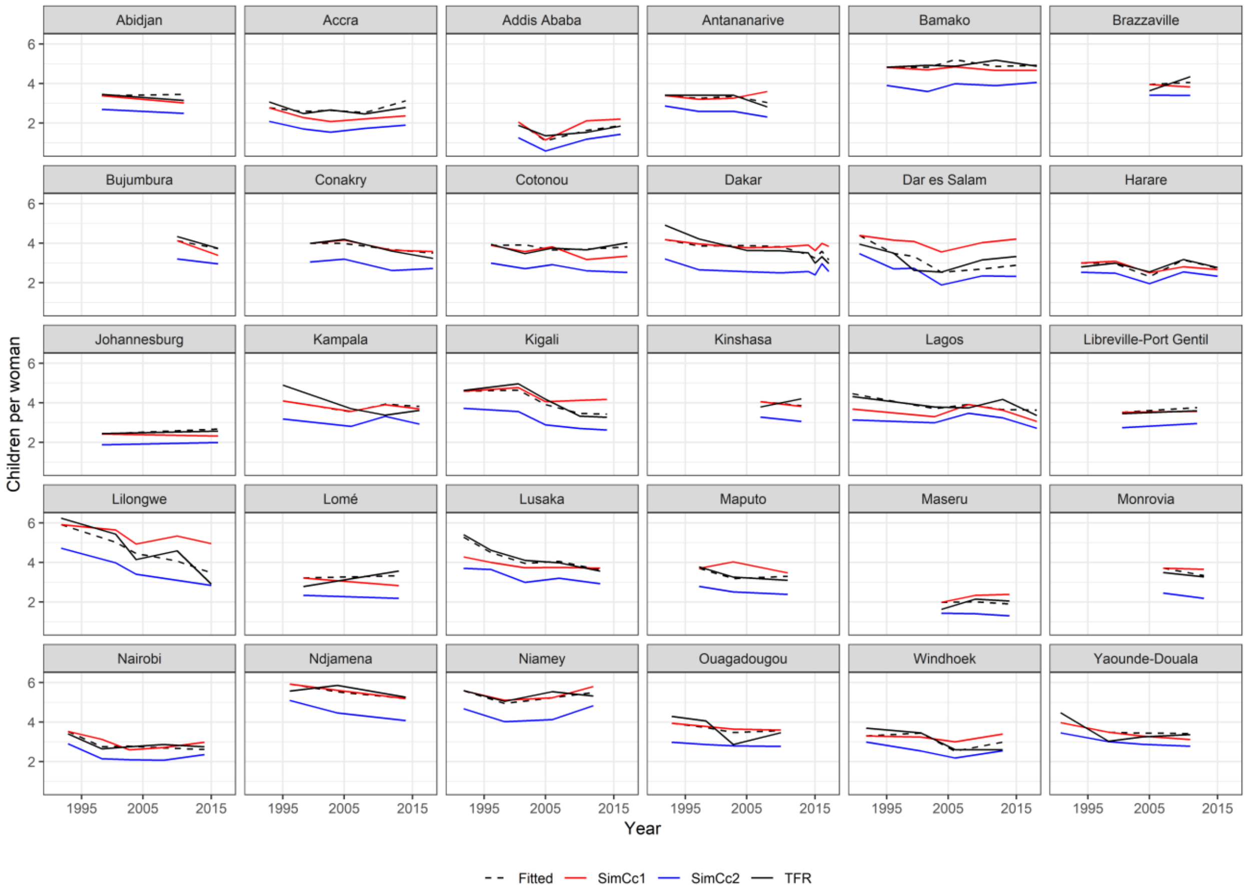


Figure A6. Effect of changes of C_i on total fertility rate.

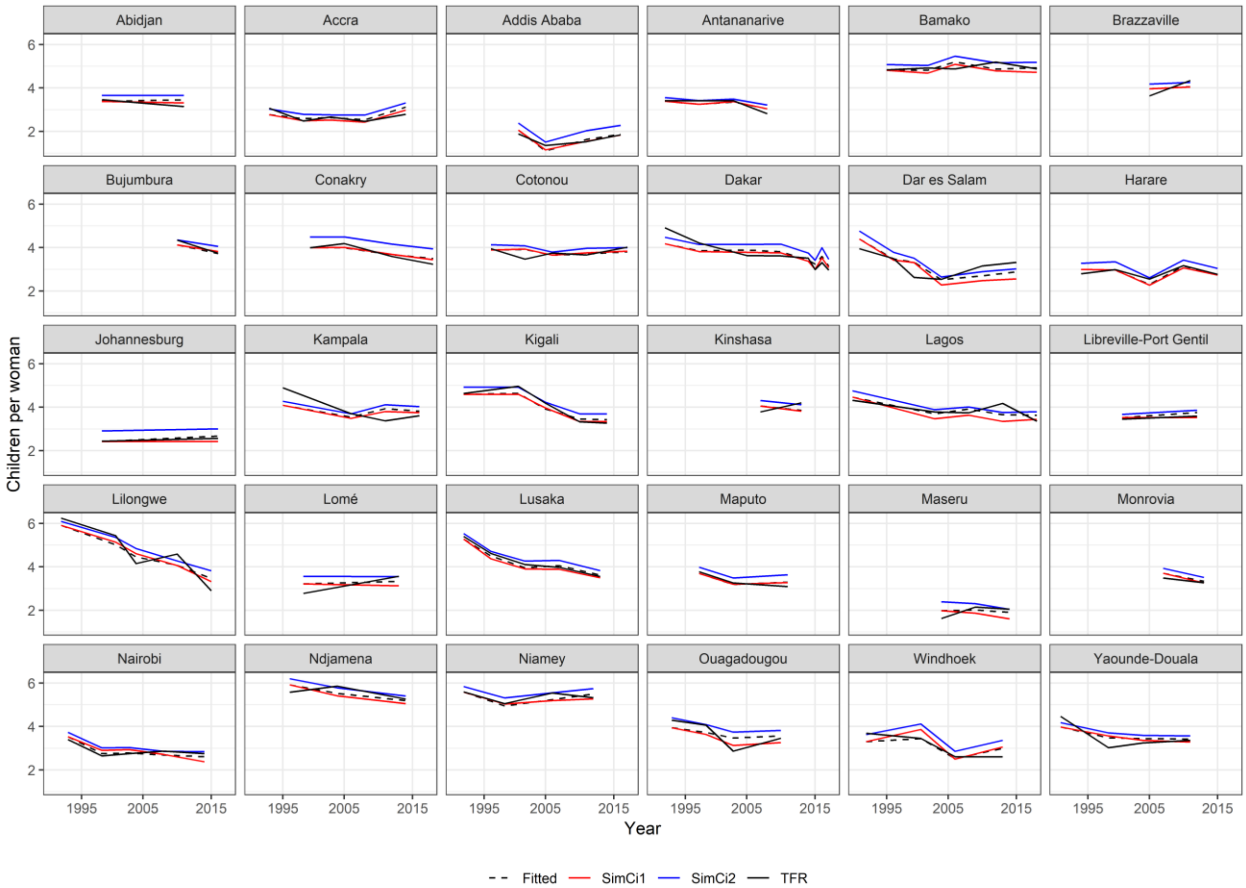


Figure A7. Effect of changes of IFS on total fertility rate.