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On the fertility transition in Africa

Income, child mortality, or education?

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Abstract: A consensus among social scientists is that fertility rates in Africa are declining. What determines these declines? I present fresh evidence that shows education, especially for women, is an important determinant of the fertility transition in Africa. This finding is consistent with the predictions of the unified growth theory and sheds important insights in explaining the sustained income growth Africa has experienced since 1995. The paper also shows that the effects of income per capita and child mortality on fertility rates are non-robust and inconsistent with the predictions of the unified growth theory.

Keywords: fertility transition, income, child mortality, education, unified growth theory, Africa
JEL classification: J13, O11, O55

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Tables and Figures at the end of the paper.

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1 Introduction

The past three decades have seen an increasing amount of empirical evidence documenting declining fertility rates in Africa (see, for example, Caldwell et al. 1992; Cohen 1998; Bongaarts 2008; Bongaarts and Casterline 2013), with the precise timing of the declines documented to have started in the late 1960s and early 1970s (see Garenne and Joseph 2002, for more details). A cursory look at statistics show that the average fertility rates are indeed declining,[1] albeit marginally from 6.54 births per woman in 1960 to 4.68 births per woman in 2013 (World Bank 2014). What determines these declines? For a long-time, this question has not only engaged the interests of social scientists but also sparked persistent debates and disagreements among them.[2] The main goal of this paper is to offer fresh evidence to this lingering question.

Understanding the underlying determinants of fertility transition in Africa is arguably important for two important reasons. First, fertility patterns are 'central in any process of structural transformation' (OECD 2015). An understanding of the mechanisms underpinning fertility transition is useful in assessing Africa's future development sustainability. Second, fertility transition creates a window of both opportunities and challenges. On the one hand, it can improve the dependency ratios in the economy by freeing up resources that can be used for improving living standards, and boost savings and investments in Africa (Das Gupta et al. 2011; Basu and Basu 2014; OECD 2015). On the other hand, it can directly affect labour market behaviour in Africa. According to OECD (2015), the demographic evolution is likely to put more pressure on the creation of productive jobs—an important ingredient for Africa's structural change; and pose imminent environmental concerns as population structure and composition change. All these have implications for Africa's future economic growth and development.

Using the demographic transition hypothesis of the unified growth theory, the present paper investigates the determinants of the fertility transitions in Africa. Based on census data of 547 districts across eight African countries, I investigate the determinants of fertility transition, both in levels and growth rates, in Africa during 1994-2010. The empirical analysis relies on two main data sources. The first data source is the Integrated Public Use

[1] There are, however, significant country-specific heterogeneities.

[2] For example, on the one hand, demographers and experts in population studies attribute declining fertility rates to the so-called proximate factors, which include biological and behavioural factors such as age at marriage, frequency of marital sex, the availability and use of contraceptives, abortions, proportions of women married or in sexual union, prevalence of permanent sterility, spontaneous intrauterine mortality, culture, and norms. Bongaarts (1978, 1982, 2008), Bongaarts et al. (1984), Cohen (1998), Stover (1998), and Bongaarts and Casterline (2013) are excellent examples of the main pioneers of this view. On the other hand, other social scientists, in particular economists, view socio-economic factors (e.g., income, prices, education, child and child mortality, costs of rearing children, women employment, health and environmental factors) as primary in explaining changes in fertility rates (see, for example, Becker et al. (1960); Becker and Lewis (1973); Gary et al. (1981); Benefo and Schultz (1996); Schultz (1973, 2007a, 2007b); and Aaronson et al. (2014).

Micro-Data Series International (IPUMS-I),[3] which provides individual level population census data. These data are cross-sectional (although in some countries they are repeated) across individuals and households. As described in the data section, I use this data source for district level analysis across eight African countries with repeated census rounds spanning between 1994 and 2010. The second data source is the United States National Oceanic and Atmospheric Association's National Geophysical Data Centre (NOAA-NGDC), which provides remotely, sensed data on night lights (henceforth lights) through the Defense Meteorological Satellite Program Operational Linescan System (DMSP-OLS).[4] I use this dataset to construct a proxy for income, and thus, circumvent the persistent absence of reliable and consistent sub-national income data in Africa (see Sutton et al. (2007) and Papaioannou (2013), for detailed discussions).

Applying pooled OLS regressions on cross-sectional district level data, I find education (measured as educational attainment at the primary, secondary, and university levels), especially for women, as the driver for the declines in fertility levels and growth rates in Africa. A point increase in the population shares of people with university, secondary, and primary education reduces future fertility rates by 0.142, 0.031, and 0.005 percentage points, respectively. The coefficient sizes for university and secondary education double when the analysis uses female population shares. The coefficient for primary education almost doubles but is insignificant. Similarly, the findings indicate that a point increase in the population shares of people with university, secondary, and primary education slows down fertility growth rates by 0.023, 0.005, and 0.001 percentage points respectively with primary education coefficient being insignificant. Again, the coefficient sizes for university and secondary education double when analysis uses female population shares. The coefficient for primary education is unchanged and insignificant. These quantitatively meaningful effects are robust to a range of specification tests and are consistent with the theoretical predictions of the unified growth theory.

Furthermore, the findings show that light intensity per capita (proxy for income per capita) positively, but marginally, affects fertility levels and growth rates in Africa. A point increase in light intensity per capita increases future fertility rates by about two children per woman and increases fertility growth by roughly 0.3 percentage points. However, these findings are non-robust echoing the discussion in Section 3.2 on the ambiguity of income per capita in explaining fertility transition in Africa. Similarly, the findings on child mortality are non-robust and inconsistent with the predictions of the unified growth theory.

The findings on education are consistent with demographic transition tenets of the unified growth theory predictions (see Galor 2011, Chapter 4), and broadly relate to both historical[5]

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[3] Available at: https://international.ipums.org/international-action/samples/

[4] Available at: http://ngdc.noaa.gov/eog/

[5] Examples of historical evidence include Murtin (2013), who investigates the long determinants of demographic transition between 1870 and 2000, and found education as the main determinant for the demographic transition across countries. Similarly, Becker et al. (2010) examines the child quantity-quality

and recent[6] empirical evidence on fertility transition around the globe. Overall, in connection to Africa's recent impressive economic performance, these findings echo claims by Schultz (2007b), Bongaarts and Casterline (2013), and Aaronson et al. (2014) that fertility rates tend to decline concurrently with other important societal changes, such as increases in schooling and declines in mortality, as countries develop.

This paper offers two main contributions to the existing literature. First, to the best of my knowledge, no previous empirical evidence tests the unified growth theory using pan-African data. Second, the paper employs remotely sensed lights data to investigate the determinants of fertility transition at the sub-national level. The use of lights data is valuable in the empirical studies of fertility transition precisely because they are good proxies for sub-national income data, especially in Africa where reliable and consistent sub-national income are unavailable or unreliable. Moreover, sub-national analysis allows controlling for unobserved country-fixed effects that naturally cannot be handled in a country-level setting, as is the case in most of the previous studies on fertility transition.

Section 2 reviews existing literature on the determinants of fertility transition. Section 3 presents Africa's trends and distributional patterns of fertility rates and their hypothesized determinants. Section 4 describes the data. Section 5 presents the empirical framework. Section 6 reports the main results and their robustness checks. Section 7 concludes.

2 Literature review

In this section, I present a brief survey of existing theoretical and empirical literature that motivates the empirical framework. Since this paper aims to explain the determinants of fertility transition in Africa under the unified growth theory framework, I focus on literature that highlight the importance of the factors that the unified growth theory closely identifies in explaining fertility transition. These factors include income, child mortality, and education.

2.1 Fertility and income

The body of literature studying the income effects on fertility decisions dates back to the seminal works of Becker et al. (1960), and Becker and Lewis (1973). These novel studies were the first to introduce the famously known children-demand models of economic theory. These two studies proposed that fertility declines as income rises because the negative substitution effect of high opportunity cost of raising children dominates the

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trade-off in Prussia in 1849 and showed that differences in education predicted cross-sectional variation in fertility in Prussian counties.

[6] A good example of most recent empirical evidence is a study by Osili and Long (2008), which shows the causal negative relation between female education and fertility rates in Nigeria. Similarly, using data from 22 countries in sub-Saharan Africa, Kravdal (2002) asserts that education level in a village or community has a negative effect on women's birth rates. Moreover, Ainsworth et al. (1996) shows that female education has a negative association with fertility rates across 14 countries in sub-Saharan Africa.

positive income effect on fertility rates. The children-demand models have indeed been instrumental in understanding both historical and contemporary fertility transitions within and across countries. In particular, they have been useful in understanding how, for example, income and prices affect household fertility decisions (Gary et al. 1981; Schultz 1973).

However, as Galor (2011, Chapter 4) proposes, the effect of income on fertility is mixed and non-robust with conflicting empirical evidence existing on how income affects fertility rates. On the one hand, Murtin (2013) shows a positive relationship between income per worker and fertility rates across countries. On the other hand, Hansen et al. (2014) show non-robust relationship between income and fertility across the United States.

2.2 Fertility and child mortality

The conventional wisdom of the workhorse economic models of fertility posits that fertility rates generally fall in response to decline in child mortality rates (see Lee 2003; Doepke 2005; Soares 2005; and Bleakley 2010, for detailed discussions). Recent empirical examples include Wilson (2015), who exploits the exogenous variation in the prevention of mother-to-child transmission of HIV to show that the Zambian pregnancy rates declined following the reduction in child mortality rates. Similarly, Conley et al. (2007) show the dominance of child mortality in predicting aggregate fertility rates in Africa. Finally, Galor (2011, Chapter 4) notes that the decline in child mortality has been viewed as plausible explanation for the onset of the decline in population growth historically.[7]

2.3 Fertility and education

The relation between education and fertility rates has been documented extensively in the literature (see, for example, Schultz 1973; Gary et al. 1981; Ainsworth et al. 1996; Kravdal 2002; Becker et al. 2010, for detailed discussions). For historical perspectives on this relation across countries, Galor (2005, 2011, Chapter 4) are excellent examples.

Moreover, Galor and Weil (1999, 2000) developed and proposed a unified growth theory that, among other things, takes child quantity-quality trade-off model at its core. This theory underlies the role of human capital development as a predictor of the fertility transition and the eventual transition from the Malthusian stagnation epoch to the era of sustained income growth across countries. According to this theory, parents preferred to invest more on children's quality (i.e. education) than their quantity to enhance their human capital accumulation. This shift led to fertility declines that sparked transition to the era of lower population growth and thus sustained income growth across countries.

One thing to note is that the existing empirical evidence, both historical and current, documents a recursive relationship between fertility and education (Becker et al. 2010;

[7] However, Galor (2011, Chapter 4) also asserts that the historical empirical evidence to support this claim is non-robust.

Cohen et al. 2011). Similar to Osili and Long (2008), our interest, however, lies in understanding the unilateral effects of education on fertility rates.

3 Background: fertility transition in Africa

3.1 Fertility trends

Figure 1 depicts the patterns of average fertility rates and population growth in Africa. Partitioning the average trends in three phases, the figure shows that in the first phase (i.e. between 1960 and 1976), fertility rates and population growth rose, with a marginal rise in fertility rates. In the second phase (i.e. between 1977 and 1993), fertility rates sharply declined while population growth rose until early 1980s and fell sharply afterwards until the end of 1993. The decline in both fertility rates and population growth during this period can mainly be attributed to the onset of the HIV/AIDS epidemic (see Young 2005, for details) and high child mortality rates across countries in Africa. Finally, the last phase, which is the focus of the present paper (i.e. between 1994 and 2013), shows that fertility persistently declined while average population growth increased and later declined but oscillated at a higher rate relative to that of 1993.

To complement the patterns described in Figure 1, Figure 2 shows average mortality growth rates increased, but remained negative or around zero. One striking pattern is that both average fertility and child mortality growth rates declined until early 1980s when the latter increased sharply and the former continued to decline. Figure 2 shows that mortality growth rates increased for about a decade until 1993 before starting to fall sharply since 1994. The sharp declines in mortality growth rates across African countries are attributed to technological advancements that led to the discovery of advanced medicines (especially Malaria vaccines), diffusion of good health practices, improvement of public health, and rise in standards of living (Murtin 2013; Wilson 2015).

3.2 Fertility distribution

Figure 3 shows the distribution of fertility rates across countries in Africa. Figures 4-6 show the box plots describing the correlates of fertility rates noted in Section 2. The figures show 5-year interval distribution during 1960-2010 across countries. The lower and upper ends of the whiskers represent the minimum and maximum values, respectively. The dots outside the box-plots represent the outliers (i.e. individual countries outside the quantile distribution).

Figure 3 shows the box plots for total fertility rates between 1960 and 2010. The figure shows that 75 per cent of countries in Africa had 5.8 childbirths per woman in 2010 relative to 7.0 childbirths in 1960. This reduction is small in a space of five decades consistent with

Bongaarts (2008), and Bongaarts and Casterline (2013) assertion that the pace of fertility decline in Africa is small.[8]

Figure 4 depicts the box plots for income per capita. Except for a few outlier countries, the majority of the countries had an average income per capita below USD2,000 in both 1960 and 2010. Thus, when comparing these patterns with those in Figure 3, it is unclear as to the direction of the relationship between fertility rates and income per capita across countries in Africa. If anything, Figures 3 also echoes Bongaarts (2008), and Bongaarts and Casterline (2013) claim that fertility transition in Africa began at relatively lower levels of national development.

Figure 5 shows the box plots for child mortality rates. The figure, depicting the distributions of both infants and under-5 mortality rates, suggests that 75 per cent of countries had higher infant (i.e. 300 per 1,000 live births) and under-5 (i.e. 160 per 1,000 live births) mortality rates in 1960 than in 2010 when the rates almost halved. Comparing with Figure 3, Figure 5 indicates a positive relationship between total fertility rates and child mortality rates.

Figure 6 shows the box plots for the average schooling years based on data from Barro and Lee (2013). The figure, which shows the distributions of both average schooling years both for total population and female population across countries, suggests that 75 per cent of countries had lower years of schooling (i.e. less than two years in 1960) for both total and female populations than in 2010 when the average years of schooling increased by a factor of five across the same countries. This figure also suggests significant improvements in human capital accumulation across countries in Africa over the past five decades. Again comparing with Figure 3, Figure 6 indicates a negative relationship between fertility rates and average schooling years.

In general, this section summarizes the trends and distributions of fertility and its hypothesized determinants during 1960-2010. These trends and distributions are, at best, the correlates of fertility transition in Africa. Before turning to the empirical section, which models these relationships in a coherent econometric framework, the next section describes the data used for analysis.

4 Data

4.1 Population census data

I employ the Integrated Public Use Micro-Data Series International (IPUMS-I),[9] which provides individual level population census data. I use this data source to construct data on fertility rates, child mortality, education, and other relevant demographics.

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[8] They argue that the median pace of change in Africa is 0.03 per year compared to 0.12 and 0.13 in Asia and Latin America, respectively.

Table 1 shows the eight countries sample under the IPUMS-I that I use in the empirical analysis. The selection of these countries is based on two key criteria. The first criterion is data availability between 1992 and 2013. This period has two main advantages: it aligns with the availability of lights data and is the period when Africa started to experience significant improvements in her economic growth. Therefore, it allows associating the determinants of fertility transition to recent income growth trajectory that the continent has experienced during this period. The second criterion, as explained in Section 5, is that the empirical analysis requires and thus uses the repeated cross-sectional nature of the data to address endogeneity concerns between fertility and its determinants.

The selected eight countries contain repeated[10] cross-sectional census data. These data offer a wide range of household demographic variables including the age and gender of individuals, the number of children born, the number of surviving children, and the number of mothers in the household. I estimate age-specific fertility rates (ASFR) and total fertility rates (TFR)[11] within five-year age groups for women between ages 15 and 49 at the district level. In addition, I calculate the difference between children born and children surviving to get the number of child deaths. Therefore, child mortality rate is the ratio of child deaths to childbirths by districts across countries.

Variables of interest contained in the IPUMS-I data also include individuals' average years of schooling, literacy levels, and educational attainment. Since Burkina Faso lacks data on average years of schooling, the baseline regression estimates[12] use educational attainment as a measure of education. This allows for use of the full sample of all 547 districts across all eight countries. Educational attainment is measured as the population share of people with university degree, secondary, and primary school education. Other important variables include employment status, family size, marital status, and household assets holdings.[13] I use these variables as controls in various specifications of the empirical models.

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[9] Available at: https://international.ipums.org/international-action/samples/

[10] As Table 1 shows, except for South Africa whose second round came after six years, the second census rounds in other countries came about ten years after the first round.

[11] Calculated as $\mathrm{TFR} = 5\sum \mathrm{ASFR}$, where ASFR is the ratio of the number of births by women in a given age group to the number of women in the same age group. For robustness checks, I construct a crude measure of fertility: the number of own children in the household per women ages 15-49. As Becker et al. (2010) point out, this crude measure also accounts for the number of surviving children in a household, which is relevant for fertility-education decisions.

[12] As explained in Section 5, the results remain robust and qualitatively the same even when I use the average years of schooling as a measure of education.

[13] These include different type of assets that individuals hold and vary considerably across countries. I employ principal component analysis (PCA) and utilize individual asset holdings to construct an asset index as a proxy for wealth and income. As shown in Section 5, the construction of this index is useful in understanding the correlates of fertility transition in typical African households where data on income are persistently absent.

4.2 Night lights data

I also employ remotely sensed data on night lights from the NOAA NGDC, archived by the DMSP-OLS.[14] I use night-lights data as a proxy for district income per capita to address the persistent absence of reliable and consistent sub-national income data in Africa similar in spirit to Sutton et al. (2007) and Papaioannou (2013). Available between -180 to 180 degrees longitude and -65 to 75 degrees latitude, these data are reported as 30 arc-second cells, which are equivalent to approximately one square kilometre at the equator.

Active since 1992, the night-lights data are recorded by satellites orbiting the earth every day between 8:00 p.m. and 10:30 p.m. local time across countries. These data are derived in two main categories: (1) as average visible and stable light free from cloud coverage, and (2) as average light with the percentage frequency of light detection.[15] Similar to most existing economic applications using these data, I employ the first format, which contains stable[16] light intensity data cleaned up of all auroral or ephemeral events and background noises. Stable lights data are recorded in digital numbers from 0 (no lights) to 63 (high light intensity). To calculate light intensity per capita, I divide the sum of light intensity extracted in a given district by district population count from the IPUMS-I data.

4.3 Other data

To control for climatic factors potentially confounding fertility transition in Africa, I also use monthly rainfall data archived by Tropical Applications of Meteorology using Satellite data (TAMSAT)[17] and ground-based observations at the University of Reading to estimate the standard deviation of rainfall around its mean. These data are available since January 1983 and are gridded at a spatial resolution of 0.0375 decimal degrees at nadir, which is approximately 4 kilometres, offering flexibility in aggregating rainfall estimates at the district level.

4.4 Summary statistics

Table 2 provides the summary statistics. First, note that a fertility growth rate between the first and second census rounds is negative. This is consistent with the trends shown in Figure 2. However, fertility rates are on average lower (i.e. an average of two births per woman) than those estimated using household surveys. These summary statistics resonate with the declining fertility trends discussed earlier. The table also shows that average mortality rates were low across countries.

Descriptive statistics on education indicate that on average the population shares of primary school and secondary school graduates are larger than the population shares of university

[14] Available at: http://ngdc.noaa.gov/eog/

[15] Read more at: http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html/

[16] I follow Lowe (2014) in masking out the geographical areas with gas flares.

[17] Available at: http://www.met.reading.ac.uk/~tamsat/cgi-bin/data/rfe.cgi/

graduates. The patterns are also consistent in population shares of educational attainment for females. In the African context, these summaries are unsurprising—in recent years, there has been significant policy push towards increasing primary and secondary school enrolment across countries.

Data on demographics show the average shares of women by their age group and population share of married women. Except for women in the 15-19 years age range, the rest of the women age groups were less than 10 per cent of the total population. Furthermore, summary on climate and distance shows that rainfall standard deviation and distance are both 5.10 millimetres and 1516.10 kilometres. Overall, except for light intensity indicators for which variances are relatively bigger to their mean, the rest of the variables seem to vary less around their mean.

The main controls used in the regression analysis therefore include: (1) child mortality rates, (2) light intensity per capita, (3) educational attainment, (4) demographic factors, which include the population share of women in the age-specific cohorts and population share of married women, (5) rainfall standard deviation, (6) district geographical location measured in absolute latitude, and (7) average district distance (in kilometres) to all key major cities.

5 Empirical strategy

This section describes the empirical strategy I use to estimate the determinants of fertility transition in Africa. The empirical strategy is divided into two parts. The first part estimates the individual-level correlates of fertility transition in Africa. As described in Section 2, the main correlates of fertility transition under the unified growth theory are income, child mortality, and education. Applying pooled OLS regressions to analyse the repeated cross-sectional individual-level IPUMS-I data, the baseline equation is:

$$\begin{aligned} \mathrm{Fertility}_{h,i,t} &= \tau_0 + \mathrm{WealthIndex}'_{h,i,t}\tau_1 + \tau_2 \mathrm{ChildMortality}_{h,i,t} \\ &+ \tau_3 \mathrm{Education}_{h,i,t} + X'_{h,i,t}\tau_4 + \theta_d + \lambda_{c,t} + \epsilon_{h,i,t} \qquad (1) \end{aligned}$$

where t is census year, and i is an individual[18] in the 15-49 years age range. Fertility as an outcome variable is measured as the ratio of children ever born to mothers in a household. I construct the Wealth Index using principal component analysis by using individuals' assets across countries over time. I use Wealth Index as individuals' income proxy. Child mortality is crudely measured as the ratio of dead children to mothers in the household. Education is measured as both educational attainment and average schooling years. In connection to

[18] An individual i is part of a household h, which is part of a district d, region r within a country c.

Section 2, the testable hypotheses are $\tau_1 \lesseqgtr 0$ (since the income effects are ambiguous), $\tau_2 > 0$, and $\tau_3 < 0$.

The vector X accounts for potential observed confounding factors including demographics, family size, employment, and marital status. All these variables are likely to confound fertility rates across households and time. To account for unobserved factors, the model includes θ_d, which captures district-level time-invariant factors that are likely to confound fertility rates across households. These include, for example, household knowledge and use of contraceptives, family planning practices, individual tastes and preferences, cultural practices, and social norms. Moreover, I include $\lambda_{c,t}$ controlling for country-by-year fixed effects, which account for potential unobserved migration of individuals across countries over time. The standard errors are clustered at household level.

The second part estimates the determinants of fertility transition in Africa, in both levels and growth rates. To do so, the empirical specification uses districts as units of analysis. The use of a lower level of geographical aggregation enables specifying the model in a way that is tractable for addressing reverse causality concerns between fertility and its determinants. That is, with districts as units of analysis and using the repeated nature of the sampled IPUMS-I data, I construct district-level cross-sectional dataset in a manner that the lagged fertility determinants in the first census waves are used as predictors of the fertility rates in the second rounds. Controlling for background factors, the main identifying assumption is that lagged variables across districts are likely to be predictors of the outcome variables in the second census rounds in the same respective districts. This relationship is not recursive, making it possible to draw relatively reliable inferences.[19]

I implement this estimation strategy on both levels and growth of fertility rates. Equation 2 shows the specified pooled OLS model using fertility levels in the second census period as an outcome variable. Similarly, equation 3 shows a similar model except with the growth of fertility rates between the first and second census rounds as an outcome variable.

$$\begin{aligned} \text{Fertility}_{d,t} = \beta_0 + \beta_1 \text{Fertility}_{d,t-n} + \beta_2 \text{Lightpc}_{d,t-n_3} \\ + \beta_3 \text{ChildMortality}_{d,t-n} + \beta_4 \text{Education}_{d,t-n} \\ + X'_{d,t-n}\beta_5 + \Gamma_{c,d,t-n} + \eta_{d,t-n} \end{aligned} \tag{2}$$

[19] However, it is important to note the limitations of this estimation strategy: (1) it does not address the potential omitted variable bias, and (2) the strategy is void of the dynamics and persistence of the effects observed on outcome variables over time. The estimated coefficients should therefore be interpreted with these two caveats in mind.

$$g(\text{Fertility}_{d,t}) = \alpha_0 + \alpha_1 \text{Fertility}_{d,t-n} + \alpha_2 \text{Lightpc}_{d,t-n}$$
$$+\alpha_3 \text{ChildMortality}_{d,t-n} + \alpha_4 \text{Education}_{d,t-n}$$
$$+X'_{d,t-n}\alpha_5 + \Phi_{c,d,t-n} + \varepsilon_{d,t-n} \quad (3)$$

where *t* is second census year, *n* is the first census year; thus *t-n* stands for the lagged variable, *d* is district.[20] Light pc stands for light intensity per capita by districts, and Mortality represents district child mortality rates. Education is measured as the district population shares of peoples' educational attainment and average schooling years across countries over census rounds. X captures the relevant controls described in Section 4.4. As above, the testable hypotheses for equation 2 are $\beta_2 \lesseqgtr 0$, $\beta_3 > 0$, and $\beta_4 < 0$. Similarly, $\alpha_2 \lesseqgtr 0$, $\alpha_3 > 0$, and $\alpha_4 < 0$ are for equation 3. Since the analysis is cross-sectional at the district level, I exclude district fixed effects but keep country-by-year fixed effects (i.e. $\Gamma_{c,d,t-n}$ and $\Phi_{c,d,t-n}$) to thwart potential time varying unobserved factors, mentioned above, that likely will bias the estimates. The standard errors are clustered at the regional level.

6 Results

6.1 Correlates

Table 3 shows the main correlates of fertility rates in our sample. Columns 1 and 2 present the results without controls except district fixed effects and country-by-year fixed effects. Columns 3 and 4 show the results when including all the controls except employment status. Columns 5 and 6 show the estimates when the regressions are restricted to only individuals' employment status (i.e. whether individuals are in wage employment or self-employed).

Across all regression specifications, the results indicate that education has a negative relationship with fertility rates. Indeed, the coefficients increase in magnitude as the level of education attainment increases across individuals. The results on child mortality show strong and positive relation with fertility rates. This finding suggests that parents are likely to have more children as child mortality increases. On the relationship with the wealth index (a proxy for income), the results suggest that individuals in second to fifth wealth quantiles had fewer children relative to individuals in the first wealth quantile. Note that these results are best viewed as correlates rather than causal: all covariates are recursive with the fertility rates making it difficult to draw causal inferences. The next sub-section presents the cross-sectional determinants of fertility transition across the sampled countries.

[20] Part of region *r* within a country *c*.

6.2 Fertility rates determinants: levels and growth rates

6.2.1 Fertility levels

Table 4 reports the baseline results of the determinants of fertility rates across the sample of countries examined. This table shows the estimates based on total population shares of education attainment across countries. Columns 1-3 show the estimates without any controls. Columns 4-6 present the estimates with all relevant controls.

The results indicate that without the controls, lagged fertility, child mortality, and lights per capita (income per capita proxy) are key predictors of fertility rates in the second census years with an R-squared of 0.63. Education is negative (but positive for population share of primary school graduates) but insignificant. The story changes when I include the relevant controls. The lagged educational attainment variables (especially for university and secondary school graduates) become negative and statistically significant predictors of fertility rates in subsequent census years. One point increase in population shares of university, secondary, and primary graduates negatively predicts future fertility rates by 0.142, 0.031, and 0.005 percentage points, respectively. The lagged child mortality becomes negative and insignificant. Similarly, the lagged light intensity per capita remains positive but marginally significant: one percentage point increase in light intensity per capita predicts a future increase of about two childbirths per women. Moreover, the R-squared increases to about 0.93 indicating the explanatory power of the included controls.

Table 5 reports closely similar results to Table 4, except, educational attainment is measured using only female population shares of university, secondary, and primary graduates. A striking thing to note in this case is that the coefficients of university and secondary graduates doubles to 0.296 and 0.064, respectively, while that of primary school graduates is statistically insignificant. The R-squared remain roughly within the same range without and with the inclusion of the controls. These results reinforce two important ideas: (1) the effect of female educational attainment on fertility rates declines, and (2) higher levels of education seem to have the most sizeable effects for females.

6.2.2 Fertility growth

Turning the attention to the effects on fertility growth rates, Table 6 reports the baseline estimates. Again, Columns 1-3 present the regression results without controls and Columns 4-6 with controls.

The story does not appear to change qualitatively even when the outcome variable is fertility growth rates. The coefficient on lagged child mortality is positive and strong with the exclusion of the controls but becomes negative with controls included. However, the coefficient is significant when population shares of secondary school graduates (i.e. in Column 5) is used in the regression. The lagged lights per capita emulate patterns similar to those before; marginally positive except for the coefficient in Column 5, which is significant at 5 per cent level.

Lagged educational attainment variables, especially population shares of university and secondary school graduates, are significant negative predictors of the declines in fertility growth rate. One percentage point increase in these variables reduces the growth in fertility rates by 0.023 and 0.005 percentage points. The coefficient on primary school graduates shares is negative but insignificant. In all specifications, the R-squared changes from about 0.54 without controls, to about 0.84 with controls, reinforcing the relevance and the explanatory power of the controls.

Similarly, Table 7 presents the estimates when education attainment is measured using female population shares of university, secondary and primary education. The results do not change compared to Table 6 except that the coefficient sizes for educational attainment variables (i.e. population shares of university and secondary school graduates) double to 0.053 and 0.011 percentage points. Again, the coefficient on primary school graduates shares is negative and insignificant, suggesting that females' higher levels of education are meaningful in explaining fertility rates.

6.3 Robustness checks

To check the reliability of the baseline estimates, this section explores the robustness of baseline regression coefficient estimates. To do so, I re-run the baseline regressions in two distinct ways: (1) I employ average schooling years as a measure of education, and (2) I use a crude measure of fertility (i.e. own child to mother ratio) as an alternative outcome variable. Tables 8 and 9 respectively show the results on fertility levels and growth rates using average schooling years as a measure of education.

Robustness tests based on average schooling years employ a sample of 507 districts across seven countries. The districts and country sample declines because the analysis excludes Burkina Faso's IPUMS-I data, which lacks information on individuals' schooling years. In both Tables 8 and 9, Columns 1 and 2 report the estimates without the controls and Columns 3 and 4 report the estimates with the controls. Overall, both tables confirm that education, especially female education, is indeed an important driving factor of both fertility levels and growth rates.

Similarly, Tables 10, 11, 12, and 13 present the estimates when the outcome variable is own child to mother ratio. As the tables show, education (measured as educational attainment) is indeed a significant factor in explaining the declining fertility patterns. Note that the lagged lights per capita and child mortality are insignificant and non-robust.

The single most important observation to emerge from the comparison of the robustness check estimates with the baseline estimates is that the former corroborate the latter—in all regression specifications, education appears to be an apparent factor in explaining fertility transition in Africa. Of course, note that these results do not say anything about the dynamics and persistence of the effects. Thus, they should be interpreted with this caveat in mind.

7 Conclusions

A consensus among social scientists is that fertility rates in Africa are declining. Using the demographic transition hypotheses of the unified growth theory, I investigate the determinants of these declining fertility trends. Utilizing micro-district census data in 547 districts across eight countries in Africa, I show that education, especially for women, is an important factor in explaining fertility transition in Africa. I also show that the effects of income per capita and child mortality are non-robust and inconsistent with the predictions of the unified growth theory.

The finding on education is, however, consistent with the demographic transition hypotheses of the unified growth theory (see Galor, 2011, Chapter 4). The finding also echoes those by Ainsworth et al. (1996), Kravdal (2002), and Osili and Long (2008), which altogether conclude the negative relationship between education and fertility rates across countries in Africa. Importantly, given that the time frame for the analysis (i.e. 1994-2010) overlaps with the period[21] when Africa started to experience positive economic growth spurts, this finding has one important policy implication—it remotely sheds insights on the role of human capital development in explaining recent impressive income growth performance in Africa.

This paper offers two main contributions to the existing literature. First, to the best of my knowledge, this is a first study to test the unified growth theory using pan-African data. Second, applying remotely sensed lights data, the paper investigates the determinants of fertility transition at the sub-national level. The use of lights data has one main advantage in studying fertility transition in Africa: they are good proxies for sub-national income data, especially in Africa where these data are lacking or unreliable. Further, sub-national analysis allows controlling for unobserved country fixed effects that naturally cannot be handled in a country-level setting, as is the case in most of the previous studies on fertility transition.

To summarize, this paper examined the determinants of declining fertility rates in Africa between 1994 and 2010. While the empirical results in this paper have broad implications for policy in Africa, the results should be interpreted with one caveat in mind—the estimates do not necessarily reflect the underlying dynamics and persistence of the effects of education on the fertility transition in Africa. Besides, it is unclear how the fertility transition empirically affects structural transformation, labour markets, and the overall economic growth in Africa. These are relevant and potential areas for informing and shaping policy in Africa and, thus, interesting for future research endeavours.

[21] That is, around 1995, as Pinkovskiy and Sala-i Martin (2014) assert.

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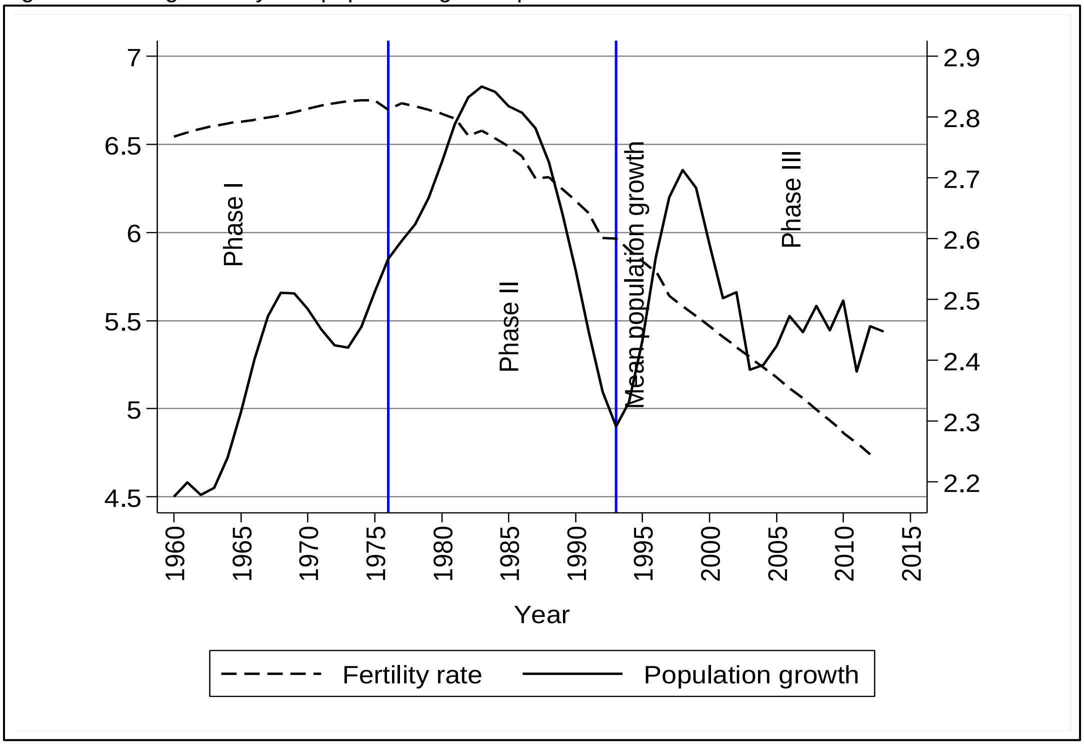
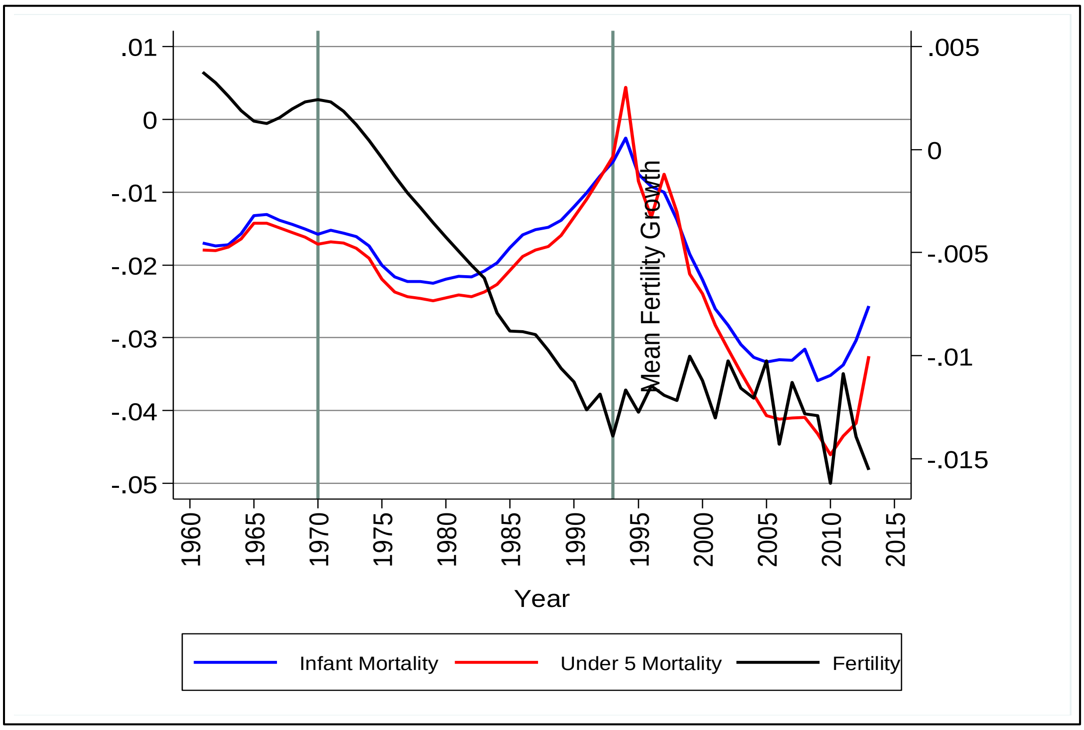
Figure 1: Average fertility and population growth patterns in Africa: 1960-2013



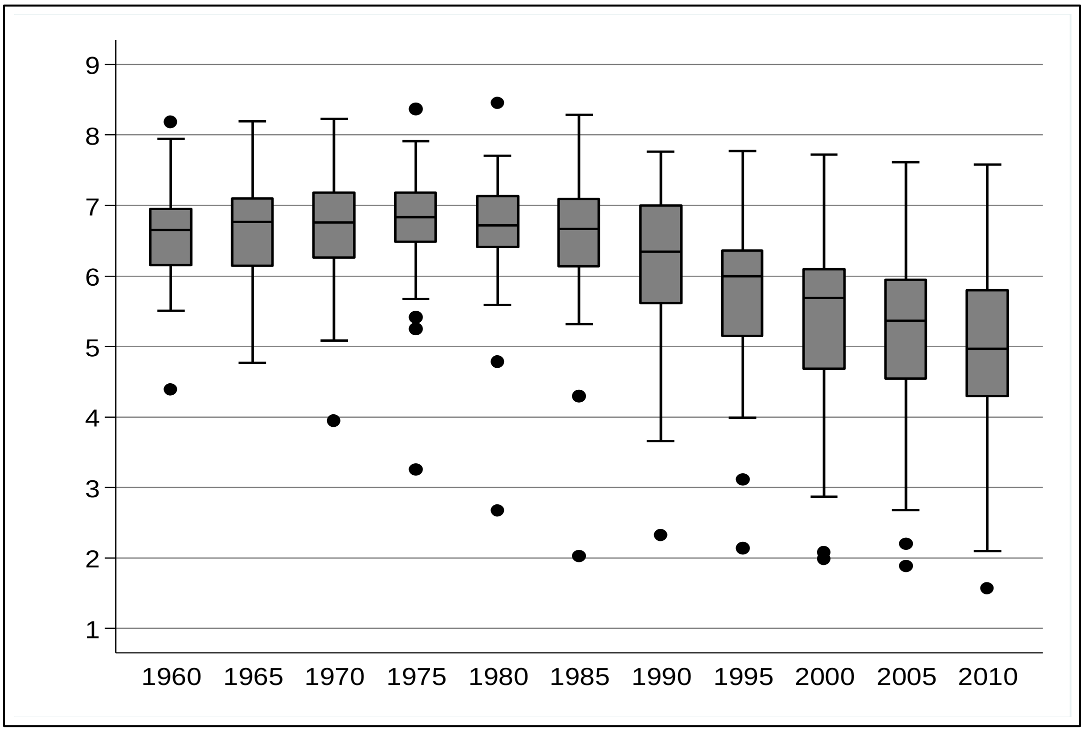
Source: Author's construction using World Bank Development Indicators (World Bank 2014).

Figure 2: Average fertility and child mortality growth rates in Africa: 1960-2013



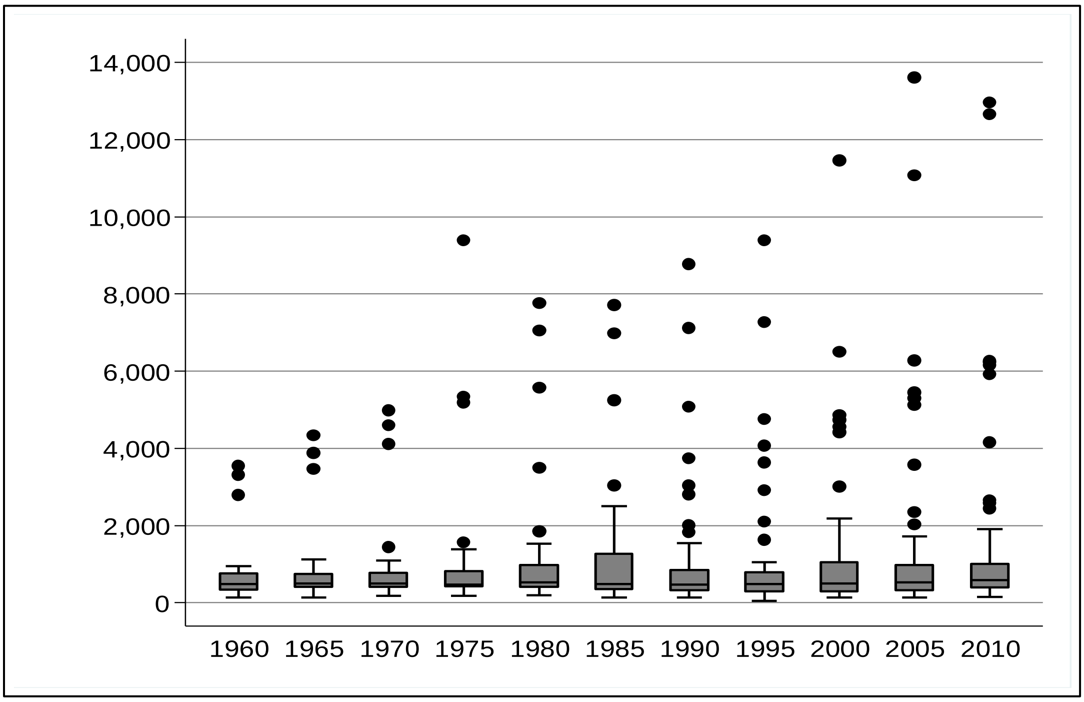
Source: Author's construction using World Bank Development Indicators (World Bank 2014).

Figure 3: Total fertility rates distribution in Africa: 1960-2010



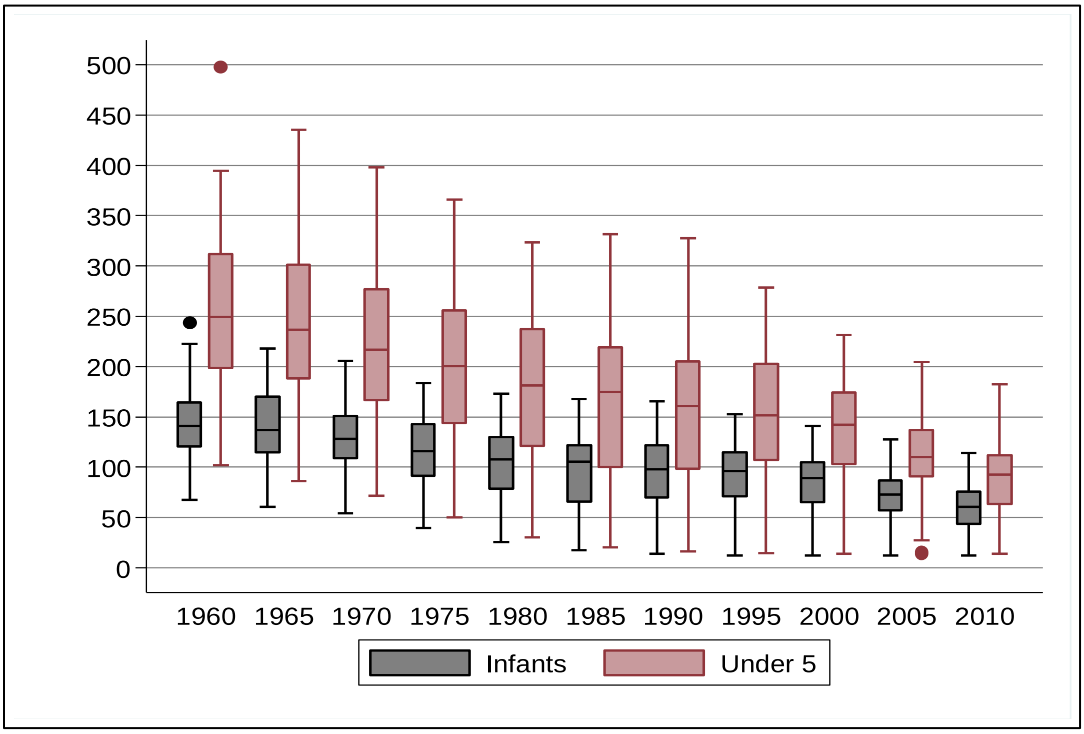
Source: Author’s construction using World Bank Development Indicators (World Bank 2014).

Figure 4: Income per capita distribution in Africa: 1960-2010



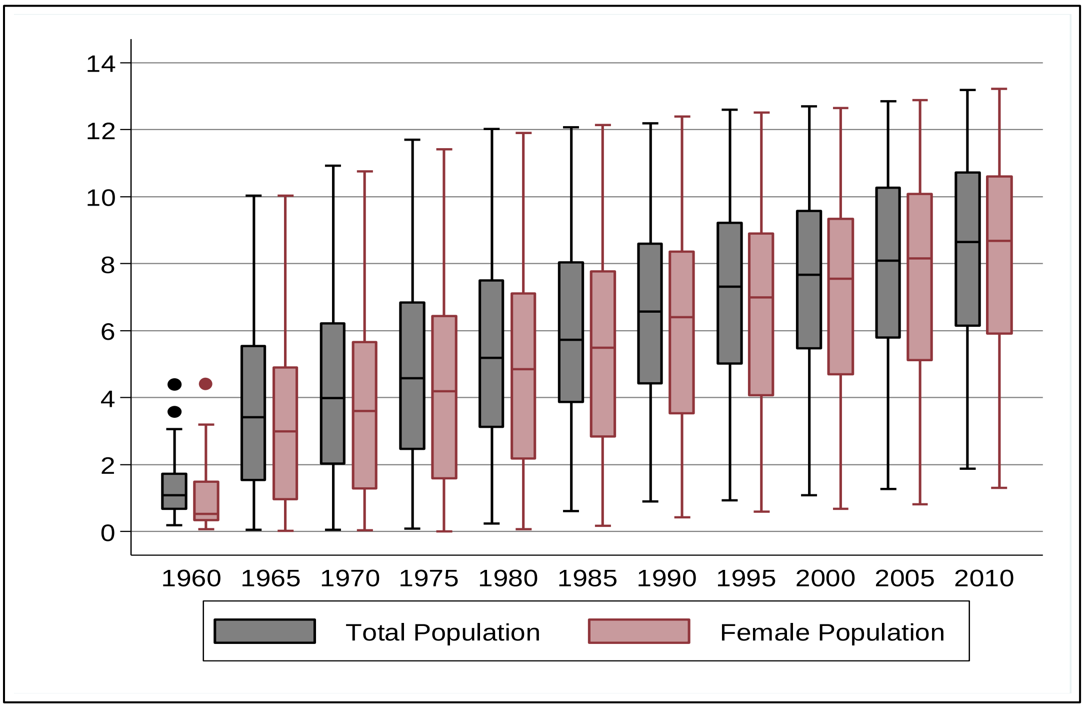
Source: Author’s construction using World Bank Development Indicators (World Bank 2014).

Figure 5: Child mortality distribution in Africa: 1960-2010



Source: Author's construction using World Bank Development Indicators (World Bank 2014).

Figure 6: Average schooling years distribution in Africa: 1960-2010



Source: Author's construction using Barro and Lee Dataset (2014).

Table 1: Country samples and census years

Country	First Census	Second Census
Burkina Faso	1996	2006
Ghana	2000	2010
Kenya	1999	2009
Malawi	1998	2008
Mali	1998	2009
Morocco	1994	2004
South Africa	2001	2007
Zambia	2000	2010

Source: Author's construction using IPUMS-I data.

Table 2: Summary statistics

Variable	Unit of Measurement	Districts	Mean	Std. Dev.	Min	Max
Fertility rate - first census	Births per woman	547	2.484	0.604	1.016	3.243
Fertility rate - second census	Births per woman	547	0.287	0.104	0.074	0.512
Fertility growth	Rate	547	-0.062	0.1	-0.279	0.072
Child mortality rate	Deaths per birth	547	-0.157	0.091	-0.413	-0.015
Light intensity per capita	Digital numbers	547	0.096	1.594	0	37.281
Mean light intensity	Digital numbers	547	2.078	5.822	0	52.782
University graduates	Proportion	543	0.055	0.056	0	0.543
Females university graduates	Proportion	515	0.023	0.026	0	0.26
Secondary graduates	Proportion	547	0.513	0.468	0.002	2.531
Females secondary graduates	Proportion	546	0.243	0.252	0.001	1.326
Primary graduates	Proportion	547	1.902	1.153	0.024	4.324
Females primary graduates	Proportion	547	0.936	0.63	0.008	2.313
Rainfall standard deviation	Millimetres	547	5.103	3.412	0.121	26.875
Absolute latitude	Decimal degrees	547	18.979	10.499	0.013	35.741
Distance to city	Kilometres	547	1516.1	1279.8	132.1	3823.1
Women aged 15-19 years	Proportion	546	0.103	0.02	0.045	0.168
Women aged 20-24 years	Proportion	547	0.085	0.013	0.018	0.119
Women aged 25-29 years	Proportion	546	0.073	0.008	0.043	0.106
Women aged 30-34 years	Proportion	547	0.061	0.006	0.043	0.089
Women aged 35-39 years	Proportion	547	0.053	0.007	0.035	0.12
Women aged 40-44 years	Proportion	547	0.043	0.008	0.022	0.12
Women aged 45-49 years	Proportion	547	0.034	0.007	0.014	0.058
Married women	Proportion	547	0.013	0.017	0	0.143

Source: Author's construction.

Table 3: Correlates of fertility transition in Africa

	(1) Fertility	(2) Fertility	(3) Fertility	(4) Fertility	(5) Fertility	(6) Fertility
Schooling years	-0.114***		-0.088***		-0.065***	
	[0.001]		[0.000]		[0.001]	
Child Mortality Rate	1.174***	1.195***	0.947***	0.945***	0.629***	0.649***
	[0.037]	[0.037]	[0.032]	[0.031]	[0.026]	[0.026]
Wealth Index - q2	0.015*	0.002	-0.100***	-0.108***	-0.163***	-0.160***
	[0.007]	[0.007]	[0.006]	[0.005]	[0.007]	[0.007]
Wealth Index - q3	-0.023**	-0.048***	-0.220***	-0.225***	-0.325***	-0.325***
	[0.007]	[0.007]	[0.006]	[0.006]	[0.007]	[0.007]
Wealth Index - q4	-0.142***	-0.171***	-0.306***	-0.323***	-0.338***	-0.350***
	[0.007]	[0.007]	[0.006]	[0.006]	[0.007]	[0.007]
Wealth Index - q5	-0.236***	-0.286***	-0.430***	-0.451***	-0.352***	-0.379***
	[0.007]	[0.007]	[0.006]	[0.006]	[0.008]	[0.007]
Primary		-0.862***		-0.482***		-0.421***
		[0.005]		[0.004]		[0.005]
Secondary		-1.275***		-1.053***		-0.786***
		[0.006]		[0.005]		[0.007]
University		-1.078***		-1.266***		-0.999***
		[0.011]		[0.010]		[0.011]
Constant	3.624***	3.422***	-6.046***	-6.286***	-5.236***	-5.270***
	[0.014]	[0.013]	[0.025]	[0.024]	[0.032]	[0.031]
Employment	No	No	Yes	Yes	No	No
Employment status	No	No	No	No	Yes	Yes
Demographic controls	No	No	Yes	Yes	Yes	Yes
Marital status	No	No	Yes	Yes	Yes	Yes
Family size	No	No	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country *x* year effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1888701	1992161	1888701	1992161	1093745	1197205
R-squared	0.151	0.146	0.431	0.425	0.380	0.374
Countries	7	8	7	8	7	8

Notes: (1) This table shows the correlates of fertility rates at the household level across eight countries in Africa. The countries included in the analysis are Burkina Faso (which is excluded from regressions using average schooling years reducing the sample to seven countries in these specifications), Kenya, Ghana, Malawi, Mali, Morocco, South Africa, and Zambia. (2) The outcome variable, 'Fertility', is the ratio of children born to mothers in a household. (3) Standard errors are clustered at the household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's estimations.

Table 4: Proximate determinants of fertility rate levels

	(1) Fertility	(2) Fertility	(3) Fertility	(4) Fertility	(5) Fertility	(6) Fertility
Fertility rate	0.287**	0.315**	0.256*	0.290	0.310	0.355
	[0.140]	[0.146]	[0.138]	[0.227]	[0.234]	[0.254]
Child mortality rate	7.763***	7.161***	8.164***	-0.201	-0.589	-0.233
	[0.991]	[1.369]	[1.047]	[0.385]	[0.425]	[0.420]
Lights per capita	0.048***	0.048***	0.047***	1.691*	2.013*	1.708*
	[0.003]	[0.003]	[0.004]	[0.972]	[1.047]	[1.004]
University share	-0.048			-0.142***		
	[0.104]			[0.034]		
Secondary share		-0.015			-0.031***	
		[0.018]			[0.007]	
Primary share			0.003			-0.005*
			[0.006]			[0.003]
Constant	0.088	0.157	0.009	1.523*	1.767*	1.584
	[0.391]	[0.405]	[0.376]	[0.888]	[0.897]	[0.980]
Demographic controls	No	No	No	Yes	Yes	Yes
Climatic factors	No	No	No	Yes	Yes	Yes
Geographical location	No	No	No	Yes	Yes	Yes
Distance to cities	No	No	No	Yes	Yes	Yes
Country x year effects	No	No	No	Yes	Yes	Yes
Observations	543	547	547	542	546	546
R-squared	0.630	0.630	0.628	0.929	0.930	0.927
Countries	8	8	8	8	8	8

Notes: (1) This table shows the pooled OLS estimates of cross-sectional determinants of fertility rate levels in 547 districts across eight countries in Africa. These countries are Burkina Faso, Kenya, Ghana, Malawi, Mali, Morocco, South Africa, and Zambia. (2) The outcome variable, 'Fertility', is the aggregate age-specific total fertility rates by districts. This variable is calculated based on second census rounds across countries. (3) All the other covariates are lagged variables during the first census rounds by districts across countries. (4) Educational attainment variables are measured as population shares of university, secondary, and primary school graduates per 1,000 people. (5) Standard errors are clustered at the household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's estimations.

Table 5: Proximate determinants of fertility rate levels—female education

	(1) Fertility	(2) Fertility	(3) Fertility	(4) Fertility	(5) Fertility	(6) Fertility
Fertility rate	0.301**	0.371**	0.315**	0.270	0.332	0.360
	[0.140]	[0.147]	[0.139]	[0.224]	[0.226]	[0.255]
Child mortality rate	7.735***	5.769***	7.397***	-0.297	-0.549	-0.164
	[0.998]	[1.434]	[1.118]	[0.429]	[0.440]	[0.419]
Lights per capita	0.055***	0.048***	0.046***	1.331	1.884*	1.673*
	[0.005]	[0.004]	[0.005]	[0.877]	[0.996]	[1.000]
University share - females	-0.224			-0.296***		
	[0.235]			[0.091]		
Secondary share - females		-0.082**			-0.064***	
		[0.035]			[0.012]	
Primary share - females			-0.006			-0.008
			[0.012]			[0.005]
Constant	0.078	0.363	0.106	1.558*	1.578*	1.422
	[0.389]	[0.409]	[0.383]	[0.845]	[0.883]	[0.980]
Demographic controls	No	No	No	Yes	Yes	Yes
Climatic factors	No	No	No	Yes	Yes	Yes
Geographical location	No	No	No	Yes	Yes	Yes
Distance to cities	No	No	No	Yes	Yes	Yes
Country x year effects	No	No	No	Yes	Yes	Yes
Observations	515	546	547	514	545	546
R-squared	0.631	0.643	0.628	0.927	0.930	0.926
Countries	8	8	8	8	8	8

Notes: (1) Using data on female educational attainment, this table shows the pooled OLS estimates of cross-sectional determinants of fertility rate levels in 547 districts across eight countries in Africa. These countries are Burkina Faso, Kenya, Ghana, Malawi, Mali, Morocco, South Africa, and Zambia. (2) The outcome variable, 'Fertility', is the aggregate age-specific total fertility rates by districts. This variable is calculated based on second census rounds across countries. (3) All the other covariates are lagged variables during the first census rounds by districts across countries. (4) Educational attainment variables are measured as population shares of university, secondary, and primary school graduates per 1,000 people. (5) Standard errors are clustered at the household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's estimations.

Table 6: Proximate determinants of fertility growth rates

	(1) g(Fertility)	(2) g(Fertility)	(3) g(Fertility)	(4) g(Fertility)	(5) g(Fertility)	(6) g(Fertility)
Fertility rate	-0.055***	-0.049***	-0.057***	-0.058*	-0.055	-0.047
	[0.011]	[0.012]	[0.011]	[0.034]	[0.036]	[0.039]
Child mortality rate	0.917***	0.784***	0.941***	-0.052	-0.118**	-0.047
	[0.119]	[0.162]	[0.128]	[0.049]	[0.057]	[0.056]
Lights per capita	0.005***	0.005***	0.005***	0.241*	0.296**	0.241*
	[0.000]	[0.000]	[0.000]	[0.129]	[0.138]	[0.132]
University share	-0.001			-0.023***		
	[0.012]			[0.006]		
Secondary share		-0.003			-0.005***	
		[0.002]			[0.001]	
Primary share			0.000			-0.001
			[0.001]			[0.000]
Constant	-0.069**	-0.049	-0.073**	0.121	0.163	0.119
	[0.029]	[0.032]	[0.028]	[0.126]	[0.127]	[0.145]
Demographic controls	No	No	No	Yes	Yes	Yes
Climatic factors	No	No	No	Yes	Yes	Yes
Geographical location	No	No	No	Yes	Yes	Yes
Distance to cities	No	No	No	Yes	Yes	Yes
Country *x* year effects	No	No	No	Yes	Yes	Yes
Demographic controls	No	No	No	Yes	Yes	Yes
Observations	543	547	547	542	546	546
R-squared	0.542	0.546	0.539	0.839	0.842	0.831
Countries	8	8	8	8	8	8

Notes: (1) This table shows the pooled OLS estimates of cross-sectional determinants of fertility growth rates in 547 districts across eight countries in Africa. These countries are Burkina Faso, Kenya, Ghana, Malawi, Mali, Morocco, South Africa, and Zambia. (2) The outcome variable, 'g(Fertility)', is the growth rate of the aggregate age-specific total fertility rates by districts between the first and second census rounds across countries. (3) All the other covariates are lagged variables during the first census rounds by districts across countries. (4) Educational attainment variables are measured as population shares of university, secondary, and primary school graduates per 1,000 people. (5) Standard errors are clustered at the household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's estimations.

Table 7: Proximate determinants of fertility growth rates—female education

	(1) g(Fertility)	(2) g(Fertility)	(3) g(Fertility)	(4) g(Fertility)	(5) g(Fertility)	(6) g(Fertility)
Fertility rate	-0.053***	-0.042***	-0.049***	-0.060*	-0.051	-0.046
	[0.011]	[0.012]	[0.011]	[0.034]	[0.034]	[0.039]
Child mortality rate	0.907***	0.601***	0.829***	-0.066	-0.116*	-0.036
	[0.121]	[0.160]	[0.129]	[0.055]	[0.058]	[0.056]
Lights per capita	0.006***	0.005***	0.005***	0.200	0.276**	0.236*
	[0.001]	[0.000]	[0.000]	[0.122]	[0.129]	[0.132]
University share - females	-0.024			-0.053***		
	[0.026]			[0.014]		
Secondary share - females		-0.013***			-0.011***	
		[0.004]			[0.002]	
Primary share - females			-0.001			-0.001
			[0.001]			[0.001]
Constant	-0.067**	-0.022	-0.059**	0.118	0.132	0.097
	[0.029]	[0.030]	[0.029]	[0.120]	[0.124]	[0.143]
Demographic controls	No	No	No	Yes	Yes	Yes
Climatic factors	No	No	No	Yes	Yes	Yes
Geographical location	No	No	No	Yes	Yes	Yes
Distance to cities	No	No	No	Yes	Yes	Yes
Country x year effects	No	No	No	Yes	Yes	Yes
Observations	515	546	547	514	545	546
R-squared	0.550	0.575	0.541	0.837	0.844	0.830
Countries	8	8	8	8	8	8

Notes: (1) Using data on female educational attainment, this table shows the pooled OLS estimates of cross-sectional determinants of fertility growth rates in 547 districts across eight countries in Africa. These countries are Burkina Faso, Kenya, Ghana, Malawi, Mali, Morocco, South Africa, and Zambia. (2) The outcome variable, 'g(Fertility)', is the growth rate of the aggregate age-specific total fertility rates by districts between the first and second census rounds across countries. (3) All the other covariates are lagged variables during the first census rounds by districts across countries. (4) Educational attainment variables are measured as female population shares of university, secondary, and primary school graduates per 1,000 females. (5) Standard errors are clustered at the household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's estimations.

Table 8: Proximate determinants of fertility rate levels—schooling years

	(1) Fertility	(2) Fertility	(3) Fertility	(4) Fertility
Fertility rate	0.273*	0.273*	0.346	0.348
	[0.143]	[0.143]	[0.265]	[0.265]
Child mortality rate	8.646***	8.567***	0.213	0.193
	[0.722]	[0.721]	[0.430]	[0.430]
Lights per capita	0.050***	0.050***	1.563	1.563
	[0.004]	[0.004]	[0.990]	[0.989]
Schooling years - total	-0.022***		-0.006**	
	[0.003]		[0.003]	
Schooling years - female		-0.024***		-0.005*
		[0.003]		[0.003]
Constant	0.133	0.154	1.383	1.375
	[0.339]	[0.339]	[1.029]	[1.030]
Demographic controls	No	No	Yes	Yes
Climatic factors	No	No	Yes	Yes
Geographical location	No	No	Yes	Yes
Distance to cities	No	No	Yes	Yes
Country *x* year effects	No	No	Yes	Yes
Observations	507	507	506	506
R-squared	0.637	0.638	0.919	0.918
Countries	7	7	7	7

Notes: (1) Using average schooling years as a measure of education, this table shows the pooled OLS estimates of cross- sectional determinants of fertility rate levels in 507 districts across seven countries in Africa. These countries are Kenya, Ghana, Malawi, Mali, Morocco, South Africa, and Zambia. (2) The number of countries and district decline because Burkina Faso's IPUMS-I data does not have data on years of schooling. (3) The outcome variable, 'Fertility', is the aggregate age-specific total fertility rates by districts. This variable is calculated based on second census rounds across countries. (4) All the other covariates are lagged variables during the first census rounds by districts across countries. (5) Standard errors are clustered at the household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's estimations.

Table 9: Proximate determinants of fertility growth rates—schooling years

	(1) g(Fertility)	(2) g(Fertility)	(3) g(Fertility)	(4) g(Fertility)
Fertility rate	-0.055***	-0.055***	-0.048	-0.048
	[0.011]	[0.011]	[0.040]	[0.040]
Child mortality rate	1.001***	0.995***	0.018	0.016
	[0.094]	[0.094]	[0.055]	[0.055]
Lights per capita	0.005***	0.005***	0.219	0.219
	[0.000]	[0.000]	[0.133]	[0.133]
Schooling years - total	-0.002***		-0.001**	
	[0.000]		[0.000]	
Schooling years - female		-0.002***		-0.001**
		[0.000]		[0.000]
Constant	-0.064***	-0.062**	0.096	0.095
	[0.024]	[0.024]	[0.146]	[0.146]
Demographic controls	No	No	Yes	Yes
Climatic factors	No	No	Yes	Yes
Geographical location	No	No	Yes	Yes
Distance to cities	No	No	Yes	Yes
Country *x* year effects	No	No	Yes	Yes
Observations	507	507	506	506
R-squared	0.566	0.568	0.825	0.825
Countries	7	7	7	7

Notes: (1) Using average schooling years as a measure of education, this table shows the pooled OLS estimates of cross-sectional determinants of fertility growth rates in 507 districts across seven countries in Africa. These countries are Kenya, Ghana, Malawi, Mali, Morocco, South Africa, and Zambia. (2) The number of countries and district decline because Burkina Faso's IPUMS-I data does not have data on years of schooling. (3) The outcome variable, 'g(Fertility)', is the growth rate of the aggregate age-specific total fertility rates by districts between the first and second census rounds across countries. (4) All the other covariates are lagged variables during the first census rounds by districts across countries. (5) Standard errors are clustered at the household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's estimations.

Table 10: Robustness checks—determinants of fertility rate levels

	(1) Fertility	(2) Fertility	(3) Fertility	(4) Fertility	(5) Fertility	(6) Fertility
Fertility rate	0.612***	0.597***	0.623***	0.784***	0.716***	0.656***
	[0.124]	[0.129]	[0.121]	[0.082]	[0.068]	[0.076]
Child mortality rate	1.006***	0.884***	0.921***	0.146***	0.061	0.034
	[0.124]	[0.143]	[0.111]	[0.054]	[0.049]	[0.051]
Lights per capita	0.000	0.000	-0.000	0.083	0.137	0.116
	[0.000]	[0.001]	[0.001]	[0.084]	[0.091]	[0.087]
University share	-0.003			-0.008*		
	[0.013]			[0.004]		
Secondary share		-0.004			-0.005***	
		[0.003]			[0.001]	
Primary share			-0.001			-0.002***
			[0.001]			[0.000]
Constant	-0.073*	-0.032	-0.047	0.069	0.152**	0.249***
	[0.041]	[0.056]	[0.050]	[0.060]	[0.062]	[0.077]
Demographic controls	No	No	No	Yes	Yes	Yes
Climatic factors	No	No	No	Yes	Yes	Yes
Geographical location	No	No	No	Yes	Yes	Yes
Distance to cities	No	No	No	Yes	Yes	Yes
Country *x* year effects	No	No	No	Yes	Yes	Yes
Observations	543	547	547	542	546	546
R-squared	0.799	0.806	0.804	0.957	0.961	0.960
Countries	8	8	8	8	8	8

Notes: (1) This table shows the pooled OLS estimates of cross-sectional determinants of fertility rate levels in 547 districts across eight countries in Africa. These countries are Burkina Faso, Kenya, Ghana, Malawi, Mali, Morocco, South Africa, and Zambia. (2) The outcome variable, 'Fertility', is the ratio of own children to women in a household by district. This variable is calculated based on second census rounds across countries. (3) All the other covariates are lagged variables during the first census rounds by districts across countries. (4) Educational attainment variables are measured as population shares of university, secondary, and primary school graduates per 1,000 people. (5) Standard errors are clustered at the household level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's estimations.

Table 11: Robustness checks—Determinants of fertility rate levels based on female education

	(1) Fertility	(2) Fertility	(3) Fertility	(4) Fertility	(5) Fertility	(6) Fertility
Fertility rate	0.628***	0.578***	0.624***	0.746***	0.740***	0.672***
	[0.131]	[0.124]	[0.122]	[0.084]	[0.067]	[0.075]
Child mortality rate	0.994***	0.772***	0.857***	0.137**	0.085	0.045
	[0.125]	[0.141]	[0.112]	[0.054]	[0.051]	[0.052]
Lights per capita	0.001	0.000	-0.000	0.062	0.113	0.107
	[0.000]	[0.001]	[0.001]	[0.075]	[0.084]	[0.088]
University share - females	-0.016			-0.014		
	[0.030]			[0.010]		
Secondary share - females		-0.012**			-0.008***	
		[0.005]			[0.001]	
Primary share - females			-0.003			-0.004***
			[0.002]			[0.001]
Constant	-0.075*	0.002	-0.027	0.058	0.116*	0.193**
	[0.041]	[0.056]	[0.051]	[0.056]	[0.060]	[0.074]
Demographic controls	No	No	No	Yes	Yes	Yes
Climatic factors	No	No	No	Yes	Yes	Yes
Geographical location	No	No	No	Yes	Yes	Yes
Distance to cities	No	No	No	Yes	Yes	Yes
Country *x* year effects	No	No	No	Yes	Yes	Yes
Observations	515	546	547	514	545	546
R-squared	0.801	0.815	0.807	0.960	0.960	0.960
Countries	8	8	8	8	8	8

Notes: (1) Using data on female educational attainment, this table shows the pooled OLS estimates of cross-sectional determinants of fertility rate levels in 547 districts across eight countries in Africa. These countries are Burkina Faso, Kenya, Ghana, Malawi, Mali, Morocco, South Africa, and Zambia. (2) The outcome variable, 'Fertility', is the ratio of own children to women in a household by district. This variable is calculated based on second census rounds across countries. (3) All the other covariates are lagged variables during the first census rounds by districts across countries. (4) Educational attainment variables are measured as female population shares of university, secondary, and primary school graduates per 1,000 females. (5) Standard errors are clustered at the household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's estimations.

Table 12: Robustness checks—determinants of fertility rates growth in Africa

	(1) g(Fertility)	(2) g(Fertility)	(3) g(Fertility)	(4) g(Fertility)	(5) g(Fertility)	(6) g(Fertility)
Child per Woman	-0.149	-0.178*	-0.136	-0.218**	-0.271***	-0.252**
	[0.099]	[0.097]	[0.096]	[0.101]	[0.098]	[0.123]
Child mortality rate	0.967***	0.773***	0.848***	0.003	-0.096**	-0.042
	[0.142]	[0.163]	[0.129]	[0.042]	[0.048]	[0.048]
Lights per capita	-0.001*	-0.000	-0.001*	0.233*	0.309**	0.253*
	[0.000]	[0.000]	[0.001]	[0.139]	[0.151]	[0.143]
University share	-0.006			-0.025***		
	[0.013]			[0.008]		
Secondary share		-0.006**			-0.007***	
		[0.002]			[0.001]	
Primary share			-0.001*			-0.002**
			[0.001]			[0.001]
Constant	-0.167***	-0.101**	-0.130***	0.017	0.110	0.116
	[0.037]	[0.048]	[0.040]	[0.086]	[0.089]	[0.105]
Demographic controls	No	No	No	Yes	Yes	Yes
Climatic factors	No	No	No	Yes	Yes	Yes
Geographical location	No	No	No	Yes	Yes	Yes
Distance to cities	No	No	No	Yes	Yes	Yes
Country *x* year effects	No	No	No	Yes	Yes	Yes
Observations	543	547	547	542	546	546
R-squared	0.511	0.538	0.520	0.848	0.856	0.843
Countries	8	8	8	8	8	8

Notes: (1) This table shows the pooled OLS estimates of cross-sectional determinants of fertility growth rates in 547 districts across eight countries in Africa. These countries are Burkina Faso, Kenya, Ghana, Malawi, Mali, Morocco, South Africa, and Zambia. (2) The outcome variable, 'g(Fertility)', is the growth rate of the ratio of own children born to women in a household by districts between the first and second census rounds across countries. (3) All the other covariates are lagged variables during the first census rounds by districts across countries. (4) Educational attainment variables are measured as population shares of university, secondary, and primary school graduates per 1,000 people. (5) Standard errors are clustered at the household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's estimations.

Table 13: Robustness checks—Determinants of fertility growth rates based on female education

	(1) g(Fertility)	(2) g(Fertility)	(3) g(Fertility)	(4) g(Fertility)	(5) g(Fertility)	(6) g(Fertility)
Child per Woman	-0.134	-0.201**	-0.136	-0.226**	-0.249***	-0.233*
	[0.105]	[0.085]	[0.096]	[0.104]	[0.090]	[0.120]
Child mortality rate	0.946***	0.617***	0.758***	-0.003	-0.082*	-0.028
	[0.145]	[0.155]	[0.127]	[0.050]	[0.049]	[0.048]
Lights per capita	0.000	-0.001*	-0.002**	0.192	0.281**	0.245*
	[0.001]	[0.001]	[0.001]	[0.131]	[0.140]	[0.145]
University share - females	-0.040			-0.054***		
	[0.029]			[0.018]		
Secondary share - females		-0.019***			-0.014***	
		[0.004]			[0.002]	
Primary share - females			-0.004**			-0.003**
			[0.002]			[0.001]
Constant	-0.163***	-0.055	-0.103**	0.005	0.070	0.066
	[0.036]	[0.043]	[0.039]	[0.081]	[0.086]	[0.098]
Demographic controls	No	No	No	Yes	Yes	Yes
Climatic factors	No	No	No	Yes	Yes	Yes
Geographical location	No	No	No	Yes	Yes	Yes
Distance to cities	No	No	No	Yes	Yes	Yes
Country *x* year effects	No	No	No	Yes	Yes	Yes
Observations	515	546	547	514	545	546
R-squared	0.523	0.582	0.536	0.846	0.857	0.842
Countries	8	8	8	8	8	8

Notes: (1) Using data on female educational attainment, this table shows the pooled OLS estimates of cross-sectional determinants of fertility growth rates in 547 districts across eight countries in Africa. These countries are Burkina Faso, Kenya, Ghana, Malawi, Mali, Morocco, South Africa, and Zambia. (2) The outcome variable, 'g(Fertility)', is the growth rate of the ratio of own children born to women in a household by districts between the first and second census rounds across countries. (3) All the other covariates are lagged variables during the first census rounds by districts across countries. (4) Educational attainment variables are measured as female population shares of university, secondary, and primary school graduates per 1000 females. (5) Standard errors are clustered at the household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's estimations.