

# The lagging fertility transition in Sub-Saharan Africa: The role of structural change

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## Executive Summary

Despite relatively sustained economic growth in at least parts of Sub-Saharan Africa over the past twenty years, the fertility transition has not much advanced in most countries in that region. Fertility rates in most countries in Sub-Saharan Africa are still at a very high level. In Sub-Saharan Africa (excluding Southern Africa), women give on average birth to more than 4.6 children during their fertile age. None of the Sub-Saharan African countries has completed the fertility transition, except South-Africa and Mauritius, but even in these two countries fertility varies greatly across socio-economic groups, so the transition is not universal. These high levels of fertility persist despite a relatively sustained economic growth and even remarkable poverty reduction in most parts of Sub-Saharan Africa.

In this paper, we analyze to what extent the lagging fertility transition in Sub-Saharan Africa can be explained by sluggish structural change. We use a novel data set covering 60 low- and middle-income countries over the period 1986 to 2018 which we constructed by merging Demographic and Health Surveys and Living Standard Measurement Surveys (or analog), enriched with data on global nighttime lights from 1992 to 2018. We use this rich dataset to explore the determinants of the fertility transition across the developing world and to identify in particular the role of structural economic change. Our key hypothesis is that structural change, i.e. a shift of employment from subsistence agriculture to more skill-intensive services and outward oriented activities accompanied by an increase in returns to education and human capital accumulation, is a key driver of the fertility transition.

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<sup>5</sup> Stephan Klasen († 27.10.2020), University of Göttingen, Department of Economics and Courant Research Center, ‘Poverty, equity, and growth in developing and transition countries’.

This paper contributes to different strands of the literature. First, it adds to the general debate about the fertility transition in Sub-Saharan Africa. Second, our analysis also provides an empirical basis regarding the relevance of unified growth models in the African context, as we focus in our analysis on some of the key drivers that are stressed by this literature. Third, Finally, we contribute to the literature on structural change in Sub-Saharan Africa as we document that it is there quite slow and different compared to other regions in the world and very heterogenous even within countries. Policy makers should be interested in the understanding of fertility trends in Sub-Saharan Africa, since under the current fertility trends its population is supposed to grow over the next 30 years by another 1.2 billion, from 1.3 billion today to 2.5 billion in 2050.

Our results strongly indicate that higher education of women, female employment in non-agricultural formal jobs, and a general increase in modern economic development as measured by an increase in nighttime light intensity are indeed important drivers of the fertility decline. We also find suggestive evidence for a complementary role of access to health insurance and an increase in relative female wages. Simulations show that if high-fertility countries in Sub-Saharan Africa had experienced the same structural change as the most demographically advanced regions in our sample, fertility levels would be at most 69 to 79% of what they are now. A Shorrocks decomposition quantifies the share of the variance in regional fertility levels that can be explained by variables related to structural change at 34 to 38%. Our results suggest that policies that enhance structural change could be very effective in accelerating the fertility transition in the Sub-Saharan African context.

Our results suggest that policies that enhance structural economic change could be a very effective trigger of the fertility transition in the Sub-Saharan African context. Such policies can include classical industrialization based on manufacturing as well as other industries and services like agro-business and the e-economy. Enhanced investment in education and health, labor market reforms that increase female labor market participation and women empowerment may accompany this process. Finally, access to formal insurance, which reduces the need for many children, can probably further push this transition. Family planning can help parents to achieve lower fertility goals, but we believe family planning alone is unlikely to play an important role in the absence of structural change.

Structural change needs to accelerate soon in Sub-Saharan Africa in order to turn the demographic burden that many countries increasingly experience into a demographic gift. The gift could arise if fertility rates eventually decline and hence a large work force coincides with a low dependency ratio. Fertility rates that finally decline in a sustained way could further boost economic development and structural change through various channels so that the process could become self-perpetuating.

**Key Words:** Demographic transition; Fertility stalls; Structural change; Sub-Saharan Africa.

**JEL Codes:** J11; J13; O12.

## 1. Introduction

Whereas the total fertility rate for the world as a whole fell from around five live births per woman in 1950/55 to 2.5 births in 2015/18, which implies that an increasing share of the world's population is living in countries where total fertility has fallen below the replacement level of 2.1 live births per woman, fertility rates in most countries in Sub-Saharan Africa are still at a very high level (United Nations DESA, 2020). In Sub-Saharan Africa (excluding Southern Africa), women give on average birth to more than 4.6 children during their fertile age (United Nations DESA, 2020). None of the Sub-Saharan African countries has completed the fertility transition, except South-Africa and Mauritius, but even in these two countries fertility varies greatly across socio-economic groups, so the transition is not universal (Bruni, Rigolini and Troiano, 2016). While some countries have not even started their transition, others have seen declines in fertility, but often these have not been lasting and ended in some cases in so called fertility stalls (Bongaarts, 2008; Garenne, 2008; Schoumaker, 2009, 2019; Grimm et al., 2020).<sup>6</sup> Since most countries have, however, entered their health transition and experienced a significant increase in life expectancy thanks to a substantial decline in child mortality, population growth rates are at very high levels, much higher of what the today developed countries experienced historically during their transition (Lee, 2003). Indeed, the under-five mortality rate declined from 156 deaths per 1,000 live births in 2000 to less than 76 deaths per 1,000 live births in 2019.<sup>7</sup> This is by historical standards a very rapid and sharp decline. Over the same period, life expectancy at birth increased, despite the HIV/AIDS pandemic, from 50 years to almost 61 years.<sup>8</sup>

These high levels of fertility persist despite a relatively sustained economic growth and even remarkable poverty reduction in most parts of Sub-Saharan Africa. On average, since the early 2000's, GDP per capita has increased in Sub-Saharan Africa by about 3% on an annual basis (Rodrik, 2018). This growth has been accompanied by an increase of total factor productivity for the first time since the early 1970's (Rodrik, 2018). In some countries, such as Côte d'Ivoire, Ethiopia and Tanzania, per capita growth has in the recent past even exceeded 7% annually.

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<sup>6</sup> A fertility stall occurs when the fertility transition has (temporarily) stopped or at least markedly slowed down. Schoumaker (2009), for example, operationalizes this concept by considering two consecutive surveys. If in the more recent survey the TFR is at least as high as in the previous survey a country or region is said to have experienced a fertility stall.

<sup>7</sup> <https://data.worldbank.org/indicator/SH.DYN.MORT?end=2019&locations=ZG&start=2019>.

<sup>8</sup> <https://data.worldbank.org/indicator/SP.DYN.LE00.IN?locations=ZG>.

The poverty head count index declined from 58% in 1999 to about 35% in 2015 (Chen and Ravallion, 2008; Cruz et al., 2015; Atamanov et al., 2020).

In Western countries, East and Southeast Asia and most parts of Latin America, such sustained rates of income growth and mortality reductions have been accompanied by significant declines in fertility. In the US, the number of children ever born per woman declined between 1850 and 1950 from about 5.5 to 2.1 while average occupational income was multiplied by eight (Jones and Tertilt, 2006). In East Asia and Southeast Asia, birth rates fell by about 50% and 30% respectively over the period 1960 to 1980 and this transition was accompanied by rapid economic growth and a massive shift of employment away from agriculture to industry (Oshima, 1983). For example, in Brazil, the total fertility rate fell from 6.3 in 1960 to 2.0 in 2005. This time span included several periods of rapid economic growth (Potter, Schmertmann and Cavenaghi, 2002).

Yet, the growth trajectory of most non-African countries was quite different of what has been observed in Sub-Saharan Africa until now. Whereas in the former economic growth came along with substantial structural change, i.e. a massive migration of labor from agriculture to industry, especially manufacturing, in the latter it has been largely based on agriculture, natural resource extraction and the informal sector (McMillan and Harttgen, 2014; de Vries, Timmer and de Vries, 2015; Diao et al 2017; Rodrik, 2018). In non-African countries, this shift in the labor composition implied increasing returns to education, a constant need to adapt to new technologies, increasing labor market opportunities for women and increasing female wage rates as well as reduced returns to child labor. Moreover, industrialization was typically also accompanied by a formalization of the economy and hence increased social protection including old age security. In a Beckerian fertility demand framework, such shifts are sought to reduce the returns to the quantity of children and increase the returns to quality, i.e. parents tend to have fewer but better educated children (Becker and Lewis, 1973; Becker, 1981). Hence, if economic growth arises without such structural change, this substitution may not take place and parents may continue to have many children with rather low levels of education.

In this paper, we analyze to what extent the lagging fertility transition in Sub-Saharan Africa can be explained by sluggish structural change. We use a novel data set covering 60 low- and middle-income countries over the period 1986 to 2018 which we constructed by merging Demographic and Health Surveys and Living Standard Measurement Surveys (or analog), enriched with data on global nighttime lights from 1992 to 2018. We merged these data at the level first-level administrative units (regions) which provides us with a regional (albeit

unbalanced) panel for in total 543 regions from 60 countries over a period of 32 years. This data gives us variation in fertility and indicators of structural change within countries and over time that we use to test whether there is a statistically and economically significant relationship between the advancement of the fertility transition and the degree of structural change. To our knowledge, our study is one of the first to look at the link between fertility and structural change in a rigorous way and it is the first to analyze the fertility transition at the subnational level across low- and middle-income countries. This level of disaggregation allows a more precise identification of relevant channels which typically get blurred when country averages are used.

Policy makers should be interested in the understanding of fertility trends in Sub-Saharan Africa, since under the current fertility trends its population is supposed to grow over the next 30 years by another 1.2 billion, from 1.3 billion today to 2.5 billion in 2050. This will be by far the highest population spurt worldwide. By 2100, Africa is projected to have a population as large as Asia. Much of Africa's population boom will come from Nigeria, currently the world's 7th most populous country and ranked 158<sup>th</sup> out of 189 countries in UNDP's Human Development Index.<sup>9</sup> It will be one of the six nations projected to have a population of over 300 million. Without structural change, Africa's population may face an insurmountable demographic burden with millions of young people without jobs and an economic and social perspective and with a serious pressure on public resources, especially on health and education infrastructure. If, in turn, this trend can be stopped and fertility rates can be significantly reduced, it may, to the contrary, turn into a demographic gift, which could perpetuate and further enhance economic growth (Bloom, Canning and Sevilla, 2003; Bloom et al., 2009; Bloom, Kuhn and Prettnner, 2016).

This paper contributes to different strands of the literature. First, it adds to the general debate about the fertility transition in Sub-Saharan Africa. Recent influential research adding to this debate includes contributions in a special issue of the *Population and Development Review*. Bongaarts (2017), for instance, stresses in this volume, as we do, the role of slow socio-economic development, poor governance, and high uncertainty as some of the key drivers. Yet, he adds that Sub-Saharan Africa has, compared to other regions, even controlling for socio-economic development in terms of mortality, income per capita, urbanization, and education, still a higher fertility on average. Bongaarts refers to this as the 'Africa effect', which he attributes to 'traditional pronatalist social, economic, and cultural practices' specific to this region. Casterline and Agyei-Mensah (2017) and Hertrich (2017) focus more on the role of

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<sup>9</sup> <http://hdr.undp.org/en/countries/profiles/NGA>.

intermediate factors that stand between more general socio-economic forces and fertility decisions, such as fertility desires and nuptiality. Singh, Bankole and Darroch (2017) argue that although desired fertility is high, it is still exceeded by actual fertility, so that there is scope to reduce fertility to some extent by promoting family planning (see also May, 2017; Tsui, Brown and Li, 2017; Harttgen and Günther, 2016). Other complementary contributions include, among others, Cohen (1998), Bongaarts (2010), Bongaarts and Casterline (2013) as well as Bloom, Kuhn and Prettner (2016). There are also a series of papers that focus specifically on ‘fertility stalls’ in Sub-Saharan Africa (Bongaarts, 2006; Bongaarts, 2008; Shapiro and Gebreselassi, 2008; Ezeh, Mberu and Emina, 2009; Shoumaker, 2009, 2019; Garenne, 2011; Garenne, 2013; Goujon, Lutz and Samir, 2015). These papers show that such stalls do indeed exist, but that their determination is highly sensitive on the time period considered. Grimm et al. (2020) show that over the last 20 years very few countries display long-lasting fertility stalls.

Our analysis also provides an empirical basis regarding the relevance of unified growth models in the African context, as we focus in our analysis on some of the key drivers that are stressed by this literature (Galor and Weil, 1996; Galor and Weil, 2000; Galor and Moav, 2002; Doepke, 2004; Cervellati and Sunde, 2005; Galor, 2011; Strulik and Weisdorf, 2008). Unified growth theory stresses the increasing role of human capital and technological progress in the production process that ultimately enhances the demographic transition. Finally, we contribute to the literature on structural change in Sub-Saharan Africa as we document that it is there quite slow and different compared to other regions in the world and very heterogenous even within countries. Influential research on structural change in Sub-Saharan Africa includes McMillan and Harttgen (2014), de Vries, Timmer and de Vries (2015), Barret et al. (2017), Diao et al (2017), Rodrik (2018), and Diao et al. (2019), among others.

The remainder of this paper is structured as follows. In Section 2, we present our dataset, introduce our key variables and show some basic descriptive statistics. In Section 3, we lay out our empirical specifications. In Section 4, we discuss our results. In Section 5, we conclude.

## **2. Data**

We constructed a novel dataset based on data from two types of surveys, Demographic and Health Surveys (DHS) and Living Standard Measurement Surveys (LSMS) or similar surveys. These surveys include individual and household level information with respect to fertility, demographics, health, education, occupation, income, and other socio-economic characteristics. Despite frequent adjustments over time, the questionnaires of DHS and LSMS

are largely harmonized across countries and survey years with respect to the key variables of interest, hence they allow to construct consistent measures across time and space.

Given the focus on individual and household level information in the DHS and LSMS, these surveys provide only limited scope to construct measures of economic development at the local level, which is an important indicator of structural change. Subnational GDP data is generally not available for most low- and middle-income countries, especially not for earlier years. For these reasons, we merge to our dataset information on nighttime light intensity as a proxy for local economic development. As Brüderle and Hodler (2018) show, nighttime lights can explain a substantial share of the variation in the local development of 29 African countries. We use a harmonized annual time series dataset on nighttime light intensity based on weather satellite recordings covering the period 1992 to 2018, constructed by Li et al. (2020). Below we explain in more detail, why we think that nighttime light intensity especially carries important information with respect to structural change.

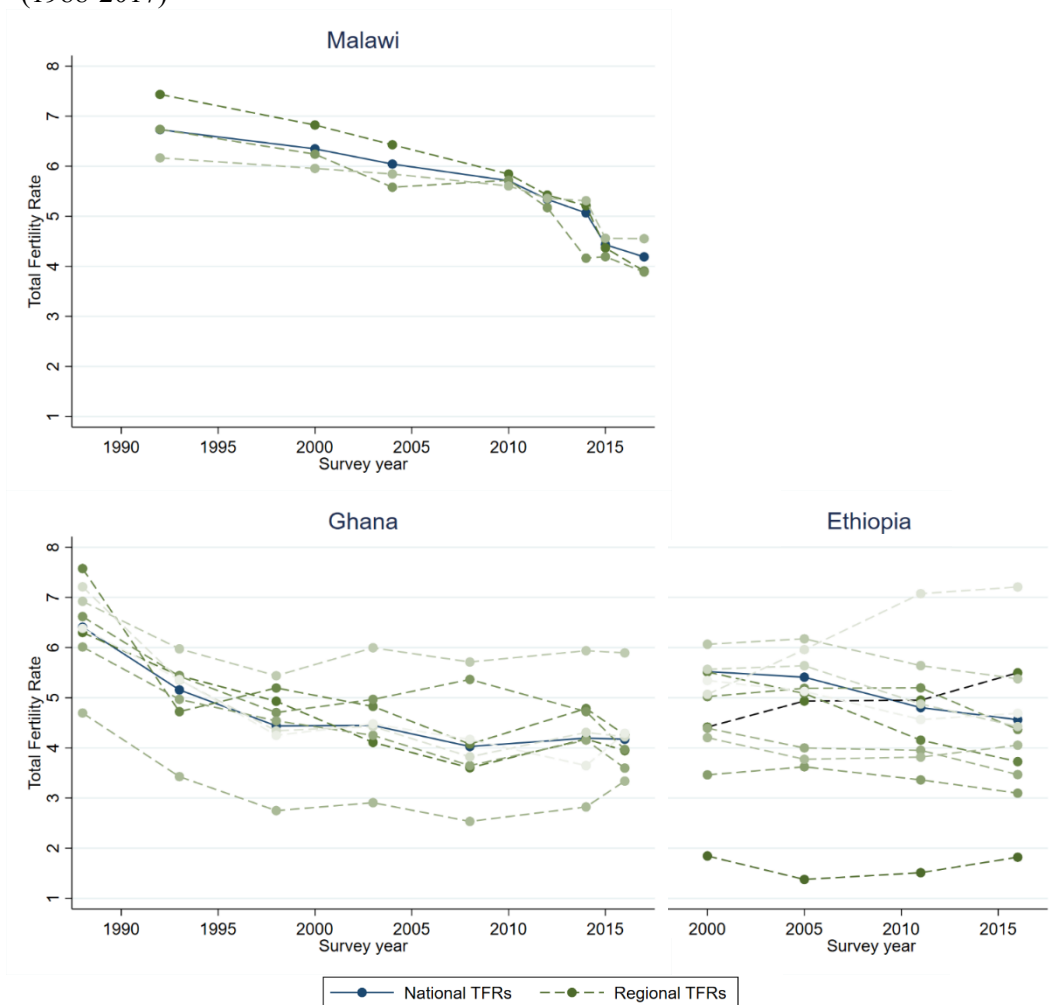
Before merging, all data was aggregated at the level of regions (first-level administrative units) in each survey year. A large share of the sampled countries experienced changes with respect to boundaries of their administrative regions during the period of observation, mostly in the form of a region being split into two or more smaller regions. If for example a country was divided into five regions until year  $t$  and was then divided into ten smaller regions from year  $t+1$  onwards, we adjusted the regions while considering two criteria: first, consistency of regional boundaries over time, and second, no unnecessary omission of information. Although such a change in boundaries would not present a problem for an analysis based on pooled observations, the adjustment is necessary when conducting fixed effects estimations. For the recoding, we used two broad approaches of regional adjustment, depending on how regional boundaries changed. The two following examples are used to illustrate this. Pakistan was divided into four regions (Balochistan, Khyber Pakhtunkhwa, Punjab, Sindh) in the 1998 and 2007 DHS. Later, the original Punjab region was split into two regions, 'Punjab' and 'Islamabad', leading to five regions (Balochistan, Khyber Pakhtunkhwa, Punjab, Islamabad, Sindh) in the 2013 and 2017 DHS. Hence, we merged the regions 'Punjab' and 'Islamabad' in 2013 and 2017 resulting in four regions with consistent boundaries in all four survey years. This allows to control for region-fixed effects, while only 'losing' two observations. Benin was divided into six regions (Atacora, Borgou, Atlantique, Mono, Oueme, Zou) in the 1996 and 2001 DHS. Later, in the 2006, 2012 and 2018 DHS, each of the six regions was split into two smaller regions, resulting in 12 smaller regions (Atacora / Donga, Borgou / Alibori, Atlantique

/ Littoral, Mono / Couffo, Oueme / Plateau, Zou / Collines). Here, instead of merging the smaller regions of the later years back to the original regions, we simply renamed the regions in 1996 and 2001 (Atacora\_96/01, Borgou\_96/01, Atlantique\_96/01, Mono\_96/01, Oueme\_96/01, Zou\_96/01). This still allows to control for region-fixed effects, since every region is at least twice in the data and regions are consistent between 1996 and 2001 and between 2006 and 2018. At the same time, we do not lose any variation, as opposed to losing 18 observations (3 x 6) had we decided to merge the 2006-2018 regions back to their original shape.

The merged dataset is a regional, unbalanced panel covering 543 regions stemming from 60 low and middle-income countries over a period of 32 years (1986-2018), providing 2370 region-by-year observations. Because of missing data, we ultimately run regressions over 1987 region-by-year observations (in our largest sample). We use the within-country and over-time variation in fertility to explore the relationship between the advancement of the fertility transition and the degree of structural change.

The main outcome variable of interest is the total fertility rate (TFR), i.e. ‘the total number of children born to a woman in her lifetime if she were subject to the prevailing rate of age-specific fertility in the population’ (WHO, 2020). The TFR is derived by calculating the average number of births a woman would have during her reproductive age if she had experienced the age-specific fertility rates observed in a specific calendar year. More specifically, we examine year-specific regional means of the TFR. Figure 1 shows the development of the TFR over time for selected countries in Sub-Saharan Africa at both the national and the regional level. While Malawi has experienced a relatively sustained decline in the TFR between 1992 and 2017 (from around 7 to around 4) not only at national level, but also across all three administrative regions, fertility trends look for example very different in Ghana and Ethiopia. Both countries display a much slower decline in the TFR at the national level that seems to have even slowed down or stopped in recent years. Moreover, not only the level of the TFR varies greatly across regions, but also its trend over time. While in some regions the fertility decline has stopped or even reversed, other regions do indeed display a more sustained decline. It is the strength of our approach to use this heterogeneity across space and time for identification.

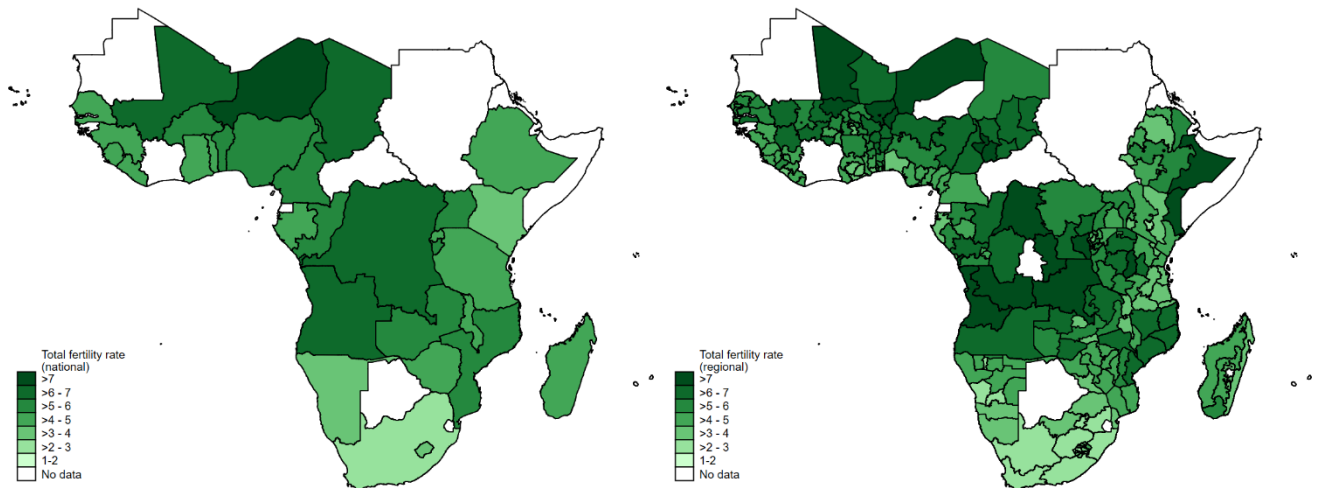
Figure 1: An illustration: national and regional trends of the TFR in Malawi, Ghana and Ethiopia (1988-2017)



Source: Own calculations using data from DHS and LSMS (and similar) surveys.

Figure 2 demonstrates that the above described regional heterogeneity of the TFR within countries is not an exception, but rather the rule across Sub-Saharan Africa. Most countries indeed show quite strong heterogeneity with respect to the TFR across administrative regions.

Figure 2: A comparison of national and regional total fertility rates in Sub-Saharan Africa



Note: The map on the left shows the national TFR and the map on the right the regional TFR for the SSA countries in our sample in the respective latest available survey year. The darker green the area, the higher the TFR. Countries/regions without fertility data are left blank.

Source: Own calculations using data from DHS and LSMS (and similar) surveys.

In order to tease out the role of structural change, we consider the following indicators. First, women's educational attainment which we measure through a vector containing the shares of women aged 15 to 59 in a region that fall into the categories 'no education', 'primary school education', and 'post-primary education'. We consider an increase in the share of women with post-primary education as a reflection of structural change that is relevant for parent's fertility decisions. Post-primary education offers the opportunity to take a job in the public sector or the private formal sector and therefore offers higher earnings opportunities, which in turn increase the time costs of women. Yet, higher earnings make childcare services obviously also more affordable. Moreover, higher education has of course a whole range of other potential effects on fertility not directly related to structural change, such as better investment decisions in health and better knowledge about contraception.

Second, we include women's employment which we capture by the shares of women aged 15 to 60 that fall into the following categories: 'agriculture' (employed, self-employed), 'not working', 'non-agricultural informal jobs' (unskilled industry workers, sales, services, domestic workers), and 'non-agricultural formal jobs' (skilled industry workers, professionals, clerical staff). Here, we consider an increase in the share of women with jobs in the non-agricultural formal sector as a reflection of structural change. Again, we assume that the higher time costs that come with such jobs may reduce fertility. Obviously, it is not always easy to make a sharp distinction between formal and informal jobs in the non-agricultural sector. However, we allocated the different occupations based on whether they are typically carried

out in a formal or in an informal setting. Moreover, we cannot rule out that the category ‘not working’ may also capture some income-generating activities, e.g. subsistence agriculture or small-scale sales or services (e.g. selling food, washing cars on the street), especially given the high share of women that report to be ‘not working’ (see Table 2).

Third, we use nighttime light intensity as a proxy of structural change. Electrification allows for industrial activities, especially manufacturing. It is therefore an important driver of employment in the private formal sector and may especially enhance female labor market participation. For each year from 1992 to 2018, Li et al. (2020) provide a gridded dataset covering the entire globe comprised of more than 725 million pixels sized 30x30 arc seconds, where one pixel corresponds to less than one square kilometer at the equator. Each pixel reports annual average nighttime light intensity as a number ranging from 0 to 63, with higher numbers indicating higher nighttime luminosity. In combination with a shape file of all 543 regions, we calculated the mean nighttime luminosity for each region in each year as the unweighted average of the numbers reported by all pixels within the region boundaries. Since the distribution of the obtained variable is heavily right-skewed, we apply a log-transformation before using it in regressions.

Gibson, Olivia and Boe-Gibson (2020) stress that the nighttime light intensity that is recorded by satellites in poorer countries easily captures urban activity, but misses most lights that can usually be found in rural areas, also because many lights available in rural areas are turned off at 1.30am when satellites take their pictures from space. In rural areas only very bright lights, such as lights emitted from a high density of street lamps, large car parks and enclave mining and industrial facilities can be detected.<sup>10</sup> Consistently, Keola et al. (2015) also report that the elasticity of the light intensity with respect to GDP is positive for countries where the share of agricultural in GDP is less than 20%, but turns negative when the share of agriculture in GDP is greater than 20%. Keola et al. (2015) further show that it is even possible for agriculture’s value-added to increase without seeing any increase in the light intensity detected from space. All this suggests that nighttime lights are well-suited for our purpose as they seem to be a good proxy for activities correlated with structural change because they do not simply capture any economic activity such as traditional farming, small rural shops and markets, but rather larger-scale modern industrial and service activities.

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<sup>10</sup> The inability of satellites to detect small, low density, settlements is also seen in Andersson et al (2019); out of 147 geo-referenced cities and towns in Burkina Faso, ranging in population from 7000 to 1.6 million, 83 of these communities (the largest of which had a population of 32,000) went undetected over the entire 21 years of satellite recordings.

Fourth, we consider social security as a further important dimension of structural change as it allows households to reduce precautionary savings, to invest more and to focus on specialization rather than diversification. It should also reduce the need to have many grown-up children to be insured in bad times and in old-age. We use insurance coverage measured as the share of households in a specific region that are covered by a health insurance scheme. This includes Community Based Health Insurance (CBHI), public health insurance schemes and private insurances including those offered by private formal and public employers. Obviously, this does only capture part of all the risks households are exposed to but data on other insurance types is scarce and hence we have to assume that other types of insurance, including live, accident and old-age insurance are correlated with the access to health insurance.

Fifth, we consider female wages, as a further indicator since we see an increase of female wages in absolute terms as well as relative to male wages as a sign of the emergence of higher productivity employment opportunities for women. These will again imply an increase in the opportunity costs of women's time and hence potentially the cost of having children. We use the log of the average female wage in a certain region while controlling for the log of the average male wage. Alternatively, we calculate the male to female wage ratio, i.e. mean male wage divided by mean female wage, also controlling for the log of the average male wage. Mean wages are based on wages of persons aged between 15 and 60 in dependent employment, that live in urban areas and work at least 20 hours in non-agricultural jobs.

We can of course think of many other dimensions of structural change that are relevant for parent's fertility decisions, but the available survey data is relatively limited in that respect. National accounts data does typically provide additional useful information such as sectoral value added but this does in most cases not exist on a disaggregated level by region. Nevertheless, we believe that our measures capture a good portion of those dimensions of structural change that are relevant for our purpose. Obviously, we cannot claim to offer a strictly causal analysis and of course our proxies leave also room for alternative transmission channels, but we believe that we expand the available literature considerably, both in terms of the level of disaggregation and in terms of the range of economic determinants considered.

Since the data availability also differs across those determinants that we do include and since we want to exclude that our results are driven by sample selection, we construct three different samples. Sample 1a contains all observations that have non-missing data on women's education, women's employment and nighttime light intensity, leading to 1982 observations stemming from 59 countries. Sample 2a contains all observations that have in addition non-

missing data on health insurance coverage, leading to 788 observations. Sample 3a contains all observations that have also non-missing data on women’s relative wages, leading to 271 observations. Additionally, we construct for each of these three samples subsamples 1b, 2b and 3b that only include observations from Sub-Saharan Africa, leading to sample sizes of 987, 414 and 197 observations respectively.

Table 1: Information on samples: included variables, regional coverage and sample size

<b>Variables with non-missing information in sample</b>	<b>Regional coverage of sample</b>	
	<b>All regions</b>	<b>Only SSA</b>
Education, employment, nighttime lights	<i>Sample 1a:</i> 1987 obs.	<i>Sample 1b:</i> 987 obs.
Education, employment, nighttime lights, insurance	<i>Sample 2a:</i> 788 obs.	<i>Sample 2b:</i> 414 obs.
Education, employment, nighttime lights, wages	<i>Sample 3a:</i> 271 obs.	<i>Sample 3b:</i> 197 obs.

Source: Own calculations using data from DHS and LSMS (and similar) surveys.

Table 2 provides summary statistics for fertility and the potential determinants for the largest possible sample. Statistics for all six sub-samples are provided in the online appendix (Tables S1 to S6). Remarkable are the quite high average TFR of 4.2 children, the relatively high share of women without any formal education (25%) and the very high share of women (43%) that do not participate in the labor market. The average male-to-female wage ratio of 1.8 indicates that women generally earn significantly less than men do.

Table 2: Summary statistics

	Obs.	Mean	St. Dev.	Min.	Max.
<i>Fertility</i>					
Regional total fertility rate (TFR)	1,982	4.226	1.575	.918	8.674
<i>Controls</i>					

Child mortality rate (deaths per 1000)	1,982	104.745	58.224	0	386.472
Urbanization rate	1,982	0.403	0.253	0	1
<i>Female education</i>					
Share of women with no education	1,982	.245	.251	0	.967
Share of women with primary school education	1,982	.349	.195	0	.850
Share of women with post-primary education	1,982	.406	.264	.003	1
<i>Female employment</i>					
Share of women working in agriculture	1,982	.242	.227	0	.952
Share of women working in non-agricultural informal jobs	1,982	.223	.142	0	.893
Share of women working in non-agricultural formal jobs	1,982	.110	.077	0	.468
Share of women not working	1,982	.424	.226	0	1
<i>Economic development</i>					
Mean nighttime light intensity	1982	3.282	8.362	0	62.626
<i>Insurance coverage</i>					
Share of household with health insurance	788	.200	.234	0	.919
<i>Relative wages</i>					
Average male wage	271	584.405	927.477	63.092	6937.672
Average female wage	271	434.863	796.719	42.697	6094.430
Male to female wage ratio	271	1.766	1.521	.204	16.639

Notes: Wages in 2011 intl. \$ PPP. Information on fertility, child mortality, urbanization, education, employment and economic development come from Sample 1a, insurance information from Sample 2a, and wage information from Sample 3a.

Source: Own calculations using data from DHS and LSMS (and analog) surveys.

### 3. Empirical specification

To explore the link between women's fertility and structural change, we use alternatively the six samples presented above. In each case, we regress the region- and year-specific total fertility rates (TFR) on several indicators of structural change. We rely on the following specifications:

$$TFR_{rct} = X'_{rct}\beta_1 + C'_{rct}\beta_2 + \beta_3 T_t + \varepsilon_{rct} \quad (\text{I})$$

$$TFR_{rct} = X'_{rct}\beta_1 + C'_{rct}\beta_2 + \beta_3(\gamma_c \times T_t) + \varepsilon_{rct} \quad (\text{II})$$

$$TFR_{rct} = \rho W TFR_{rct} + X'_{rct}\beta_1 + C'_{rct}\beta_2 + \beta_3(\gamma_c \times T_t) + \varepsilon_{rct} \quad (\text{III})$$

$$TFR_{rct} = \rho W TFR_{rct} + X'_{rct}\beta_1 + C'_{rct}\beta_2 + \beta_3(\gamma_c \times T_t) + v_{rc} + \varepsilon_{rct} \quad (\text{IV}),$$

where  $TFR$  is the total fertility rate in region  $r$  and country  $c$  at time  $t$ ,  $X$  is a vector with indicators of structural change and  $C$  is a vector of control variables, namely urbanization and child mortality. Obviously, urbanization and child mortality might themselves partly be reflections and consequences of structural change, but because they clearly have also drivers that cannot be subsumed under structural change we treat them as additional controls.

We model time effects and spatial correlations in different ways. In model I, we only control for general time-effects ( $T$ ). In model II, we interact them with country-fixed effects ( $\gamma$ ) in order to account for country-specific time-effects ( $\gamma \times T$ ). In Model III, we additionally control for the spatial correlation of fertility, i.e. we add the spatially lagged regional TFR, WTFR, as a control. To do so, we first estimate a spatial weight matrix using the geographical information of latitude and longitude (Kondo, 2017). This matrix is then used to compute a region-specific spatially lagged variable that accounts for spatial dependencies across regions within a specific country. Finally, model IV makes use of the panel structure of the dataset and includes in addition region-fixed effects ( $\nu$ ). While adding region-fixed effects allows in principle to control for a sizeable portion of unobserved heterogeneity, our preferred specification is specification III and we see specification IV rather as a robustness check. The reason is that we still have a substantial portion of regions for which we have only one observation (provide share), for many we have only two (provide share). Regions with one observation do not enter our region-fixed effects estimation which means we lose power and may get biased estimates. Regions with only two observations do also only provide limited variation for a within-estimator.

It must also be noted that our approach is not fully immune to reverse causality. A high TFR indicates that women not only have more children, but also start childbearing early. This is likely to decrease their level of education and hence also to influence their occupational choice and wage. Hence, we won't make any causal claims, but we will provide a sufficient number of alternative estimates and specifications to show that our results are relatively robust to the remaining sources of bias.

## 4. Results

### 4.1. Main results

This section presents our findings regarding the relationship between the regional TFR and various indicators of structural change. For each indicator (group), we focus on the results from

the largest possible sample. However, when relevant, we also refer to the results from subsamples, especially the Sub-Saharan Africa samples. Tables 3 to 5 below show the corresponding results. In each table, each column refers to one regression. Column (1) uses OLS with general time-effects, Column (2) includes country-specific time-effects, Column (3) also includes the spatial lag of the regional TFR as a control and Column (4) uses the dataset's panel structure by accounting for region-fixed effects, yet for the reasons given above these are not our preferred estimates. In all regressions, we control for the child mortality rate as well as for the urbanization rate. Since these variables serve as control variables and are not the focus of our analysis, we will not discuss their coefficients in detail, but generally we find that the coefficient associated with child mortality is positive and highly statistically significant across almost all samples specifications, while the urbanization coefficient is generally negative and often (though not always) also statistically significant.

Table 3: Regressions of the TFR on female post-primary education, female participation in non-agricultural formal jobs and nighttime light intensity (Sample 1a)

	Sample 1a Spec. I (1)	Sample 1a Spec. II (2)	Sample 1a Spec. III (3)	Sample 1a Spec. IV (4)
Child mortality rate (deaths per 1,000)	0.010*** (0.0018)	0.004*** (0.0013)	0.004*** (0.0012)	0.005*** (0.0009)
Urbanization rate	-0.274 (0.3387)	-0.688** (0.3137)	-0.726** (0.3151)	0.536 (0.4034)
Share of women with primary school education	-0.516 (0.5293)	-1.451* (0.7781)	-1.464** (0.7338)	-0.891 (0.7401)
<b>Share of women with post-primary education</b>	<b>-1.688*** (0.4858)</b>	<b>-2.177*** (0.4581)</b>	<b>-2.166*** (0.4274)</b>	<b>-3.445*** (0.8380)</b>
Share of women that do not work	0.287 (0.3898)	-0.114 (0.2297)	-0.106 (0.2118)	-0.028 (0.1212)
Share of women working in non-agricultural informal jobs	1.463*** (0.5228)	0.059 (0.3620)	0.071 (0.3342)	0.214 (0.2075)
<b>Share of women working in non-agricultural formal jobs</b>	<b>-2.514** (0.9489)</b>	<b>-1.428 (0.8665)</b>	<b>-1.352* (0.7840)</b>	<b>-1.007* (0.5175)</b>
<b>Ln mean nighttime light intensity</b>	<b>-0.184*** (0.0348)</b>	<b>-0.123*** (0.0274)</b>	<b>-0.120*** (0.0262)</b>	<b>-0.028 (0.0199)</b>
General time-effects	yes	no	no	no
Country-specific time-effects	no	yes	yes	yes
Spatial lag	no	no	yes	yes
Region-fixed effects	no	no	no	yes
R-Squared	0.633	0.863	0.867	
Observations	1,982	1,982	1,982	1,982
Region groups	528	528	528	528

Notes: Each column refers to one regression. 13 regions have information on female occupation, female employment and/or nighttime lights for only one survey year and thus do not contribute to the fixed-effects regressions in Column (4).

Source: Own calculations using data from DHS and LSMS (and similar) surveys.

### *Female post-primary education*

The estimated effects associated with female post-primary education are, throughout almost all samples and specifications, negative and statistically highly significant. Note that the share of women with no education is always the reference category. Using our largest sample, holding child mortality and urbanization as well as the employment structure and nighttime light intensity constant, and accounting for country-specific time-effects, we find an effect of about 0.22 less children per women as the share of women with completed post-primary education increases by ten percentage points (see Column 2, Table 3). This effect is robust to the inclusion of both the spatial lag of the TFR and region-fixed effects (see Column 3 and 4, Table 3), with the latter the coefficient even increases quite strongly. In terms of coefficient size and significance, there are no mentionable differences across the different samples except that in the very small samples with region-fixed effects, significance vanishes. Hence, there are strong reductions in fertility associated with an expansion of female post-primary education. The effects for primary education relative to no education are also negative, but they are only two thirds the size as those associated with post-primary education (except in the smallest samples) and sometimes of less statistical significance. We do not observe systematic differences for the SSA subsample (see Online Appendix).

### *Female non-agricultural formal employment*

To identify the effects associated with the female employment structure, we use as explanatory variables the share of women in different activities, taking the share of employment in agriculture as reference category. We consistently find negative effects associated with the share of women employed in non-agricultural formal jobs. In our largest sample, accounting for country-specific time trends, the total fertility rate decreases by 0.14 when this share increases by ten percentage points (however, the coefficient is not statistically significant). For Sub-Saharan Africa, the coefficient is more than twice as large, at around -0.32 and highly statistically significant (see Online Appendix). The effect is robust to the inclusion of the spatial lag of the TFR, but shrinks considerably in the fixed effects regressions. While the general pattern persists across all samples, the coefficients of the region-fixed effects specification are generally insignificant. This is not very surprising, given that sample sizes shrink quite

markedly and that employment is strongly correlated with education, which is also included in the regression. We do not find any systematic patterns regarding the share of women in non-agricultural informal jobs or regarding the share of women without work. Overall, a shift from the agricultural sector towards the non-agricultural formal sector seems to significantly contribute to a reduction in fertility, and this effect seems particularly strong in Sub-Saharan Africa.

### *Nighttime light intensity*

The association between nighttime light intensity and the regional TFR is generally negative and significant in the larger samples without region-fixed effects. When using the smaller samples (2b, 3a, 3b), the coefficients stay negative but lose significance. In our largest sample, the effect size is in the order of -0.12 to -0.18 children for a doubling of nighttime light intensity. If we use only the subsample with countries in Sub-Saharan Africa we find an effect of -0.05 to -0.07 (see Online Appendix). The smaller effect in the SSA sample might be due to the fact that the level and variation of nighttime lights in this region is markedly lower as in other regions. Still, the results suggest, that there is a non-neglectable effect that can be attributed to industrialization and an expansion of formal large-scale activities on top to what is already captured by female education and employment opportunities.

Table 4: Regressions of the TFR on female post-primary education, female participation in non-agricultural formal jobs, nighttime light intensity and health insurance coverage (Sample 2a)

Indicators of structural change	Sample 2a	Sample 2a	Sample 2a	Sample 2a
	Spec. 1a	Spec. 1b	Spec. 1c	Spec. 1d
	(1)	(2)	(3)	(4)
Child mortality rate (deaths per 1,000)	0.012*** (0.0026)	0.007*** (0.0017)	0.007*** (0.0013)	0.006*** (0.0012)
Urbanization rate	0.028 (0.4138)	-0.416 (0.2570)	-0.515* (0.2807)	0.442 (0.3319)
Share of women with primary school education	-1.003* (0.5376)	-1.791** (0.7804)	-1.793** (0.7236)	-0.295 (1.0197)
<b>Share of women with post-primary education</b>	<b>-2.018*** (0.5841)</b>	<b>-2.598*** (0.4439)</b>	<b>-2.526*** (0.4222)</b>	<b>-2.763** (1.0730)</b>
Share of women that do not work	-0.185 (0.4307)	-0.159 (0.2384)	-0.125 (0.2156)	-0.222** (0.1091)
Share of women working in non-agricultural informal jobs	0.532 (0.8122)	-0.087 (0.4987)	-0.019 (0.4462)	-0.559** (0.2324)
<b>Share of women working in non-agricultural formal jobs</b>	<b>-3.298*** (1.1312)</b>	<b>-1.077 (0.9743)</b>	<b>-0.925 (0.7788)</b>	<b>-0.294 (0.4455)</b>

<b>Ln mean nighttime light intensity</b>	<b>-0.167***</b> <b>(0.0453)</b>	<b>-0.150***</b> <b>(0.0435)</b>	<b>-0.145***</b> <b>(0.0408)</b>	<b>0.011</b> <b>(0.0246)</b>
<b>Share of households with health insurance</b>	<b>-0.664*</b> <b>(0.3402)</b>	<b>-0.833**</b> <b>(0.4104)</b>	<b>-0.851**</b> <b>(0.3763)</b>	<b>-0.265</b> <b>(0.2559)</b>
General time-effects	yes	no	no	no
Country-specific time-effects	no	yes	yes	yes
Spatial lag	no	no	yes	yes
Region-fixed effects	no	no	no	yes
R-Squared	0.680	0.873	0.881	
Observations	788	788	788	788
Region groups	425	425	425	425

Notes: Each column refers to one regression. 180 regions have information on female occupation, female employment, nighttime lights and/or insurance coverage for only one survey year and thus do not contribute to the fixed-effects regressions in Column (4).

Source: Own calculations using data from DHS and LSMS (and similar) surveys.

### *Social security*

Next, we discuss the effects associated with health insurance coverage. Since insurance ownership is not available in all data sets, this can only be explored for a reduced sample of 788 region-year observations or 414 region-year observations if we focus on SSA alone. The information on insurance has mostly been collected in more recent years so that these samples do not mirror relationships in earlier years (1990's). The effect of insurance coverage is always negative, mostly significant and sizeable. The largest effects are obtained when using pooled OLS regressions and accounting for country-specific time-effects and the spatial lag of the regional TFR. In this case, for the global sample, the estimates suggest that a ten percentage-point increase in insurance coverage would reduce the TFR by about 0.09 children per women controlling for all the other features of structural change discussed above. The coefficient remains negative, but turns insignificant in the fixed-effects specification, but again this is not our preferred specification. For the SSA sample, the effect is much larger, indicating a reduction by up to 0.26 children (OLS with country-specific time trends). This effect also remains statistically significant to the introduction of region-fixed effects, yet decreases to 0.18 (see Online Appendix). Health insurance thus seems to further reduce fertility on top of female post-primary education, female non-agricultural formal employment and industrialization as proxied by nighttime light intensity, especially in the Sub-Saharan African context.

Table 5: Regressions of the TFR on female post-primary education, female participation in non-agricultural formal jobs, nighttime light intensity and female wage levels (Sample 3a)

Indicators of structural change	Sample 3a	Sample 3a	Sample 3a	Sample 3a
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	Spec. 1a (1)	Spec. 1b (2)	Spec. 1c (3)	Spec. 1d (4)
Child mortality rate (deaths per 1,000)	0.010*** (0.0026)	0.004** (0.0017)	0.003** (0.0014)	0.005** (0.0022)
Urbanization rate	-0.905** (0.4274)	-0.638** (0.2950)	-1.172*** (0.3634)	-0.163 (0.8943)
Share of women with primary school education	-1.638* (0.8487)	-3.406** (1.5699)	-3.371*** (1.1395)	-0.058 (2.3284)
<b>Share of women with post-primary education</b>	<b>-1.396*</b> <b>(0.6719)</b>	<b>-2.498***</b> <b>(0.8114)</b>	<b>-2.154***</b> <b>(0.7566)</b>	<b>0.056</b> <b>(1.8094)</b>
Share of women that do not work	0.760 (0.4645)	0.256 (0.3716)	0.462 (0.3892)	0.212 (0.5664)
Share of women working in non-agricultural informal jobs	0.456 (0.4269)	0.257 (0.9422)	0.255 (0.7587)	-0.351 (1.1304)
<b>Share of women working in non-agricultural formal jobs</b>	<b>-4.782**</b> <b>(1.8726)</b>	<b>-5.258</b> <b>(3.3789)</b>	<b>-4.105***</b> <b>(1.4930)</b>	<b>-1.576</b> <b>(1.5513)</b>
<b>Ln mean nighttime light intensity</b>	<b>-0.049</b> <b>(0.0534)</b>	<b>-0.052</b> <b>(0.0521)</b>	<b>-0.035</b> <b>(0.0489)</b>	<b>-0.011</b> <b>(0.0519)</b>
Ln male wage	-0.038 (0.1802)	0.074 (0.2135)	0.106 (0.1645)	0.077 (0.1269)
<b>Ln female wage</b>	<b>-0.199*</b> <b>(0.1119)</b>	<b>-0.264***</b> <b>(0.0628)</b>	<b>-0.196***</b> <b>(0.0473)</b>	<b>0.041</b> <b>(0.0536)</b>
General time-effects	yes	no	no	no
Country-specific time-effects	no	yes	yes	yes
Spatial lag	no	no	yes	yes
Region-fixed effects	no	no	no	yes
R-Squared	0.691	0.831	0.859	
Observations	271	271	271	271
Region groups	146	146	146	146

Notes: Each column refers to one regression. Wages in 2011 intl. \$ PPP. 56 regions have information on female occupation, female employment, nighttime lights and/or relative female wages for only one survey year and thus do not contribute to the fixed-effects regressions in Column (4). Source: Own calculations using data from DHS and LSMS (and similar) surveys.

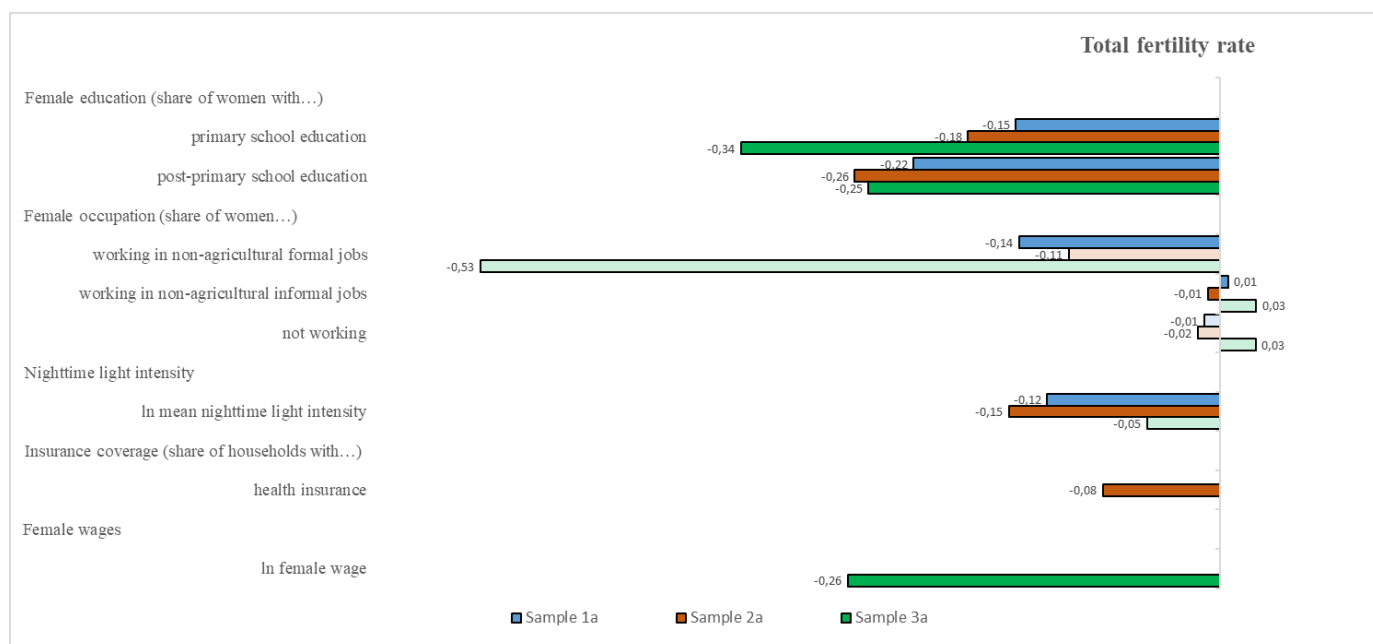
### *Female wage levels*

The limited availability of quality wage data forces us to work with a relatively small and selected sample when we explore the association between female wages and fertility. Especially countries from Sub-Saharan Africa are over-represented in this sample. Recall, as measures for female wages, we use two alternative specifications: (ln) female wages and the male-female wage ratio. In both cases, we control for (ln) male wages. In all regressions, we also control for female education, female employment and nighttime light intensity. For both measures, the effects mostly have the expected sign, but they are not statistically significant if we only control

for general time-effects. Yet, in the preferred specification with country-specific time-effects, the coefficients are statistically significant. For this specification, the coefficient on  $\ln$  female wages is 0.28, i.e. a doubling of average female wages reduces fertility by 0.26 children per woman. This is a rather modest effect and it further decreases to 0.2 children when introducing spatial lags. When we introduce region-fixed effects, the effect associated with female wages becomes even positive, but very small and insignificant. The male-female wage ratio shows overall a positive association with the regional TFR, i.e. the larger the difference between average male and female wages becomes, the higher the TFR. Again, this effect is not robust to the fixed effects specification and changes the sign of the coefficient (again, very small). We do not find any particularities regarding relative female wages and fertility for our SSA subsample (see Online Appendix). These results provide some suggestive, yet not very robust evidence that higher female wages enhance the fertility decline. Given the small sample sizes and hence low power and the fact that we control for female education and employment, it is not surprising that the effects are rather small and not very precisely estimated.

Figure 3 provides an overview of the effect sizes of the various indicators of structural change used in our analysis. The coefficients are obtained from OLS regressions with country-specific time-effects using the full list of covariates. It can be seen that especially female (post-primary) education and women's employment in non-agricultural formal jobs, but also industrialization as proxied by nighttime light intensity are important determinants of the fertility transition. Health insurance coverage seems to be more important in the Sub-Saharan African context compared to the rest of low- and middle-income countries. female wages levels do also play a role, however, as mentioned before, the coefficients are not very well identified.

Figure 3: Determinants of fertility – overview of the associated effect sizes



Notes: All coefficients were obtained from regressions using Sample 1a/2a/3a and specification 1b (i.e. columns (3) from Tables 3, 4 and 5). Transparent bars indicate non-significant coefficients ( $p > 0.1$ ). The effect sizes for female education, female occupation and insurance coverage correspond to a ten percentage-point increase in the respective categories. The effect sizes for nighttime light intensity and female wages correspond to a doubling of these measures.

Source: Own calculations using data from DHS and LSMS (and similar) surveys.

## 4.2. The unlocked potential of industrialization and structural change

### *Some illustrative simulations*

To put into perspective the magnitude with which structural change transports the fertility transition, we performed the following simulation. We identified those regions in our sample that are outside Sub-Saharan Africa and are particularly advanced in their fertility transition, i.e. regions that have shown a very low TFR in recent years and where the fertility decline has been smooth (no temporary stalls). These criteria led to the following 14 regions from nine different countries: Armenia (Gegharkunik, Aragatsotn), Bangladesh (Barisal), Cambodia (Kampong Speu, Kampong Chhnang), Colombia (Pacifica, Oriental), India (Haryana, Rajasthan), Indonesia (West Sumatera, North Sulawesi), Jordan (Balqa/Amman/Madaba), Peru (Junin), and the Philippines (National Capital Region). For these 14 regions, we then computed the means for all variables capturing structural change included in our regression models.<sup>11</sup> We then selected the ten countries in Sub-Saharan Africa that have the highest national TFR in the most recent survey year and for which the fertility decline, if any, has slowed down or even

<sup>11</sup> Female education and nighttime light intensity data are available for all fourteen regions, female employment data for thirteen and insurance data for ten. For none of the selected regions, wage data is available, we thus conduct the predictions without considering the effects of relative female wages.

come to a halt. Hence, considering also data availability, we selected the following countries: Angola, Benin, Cameroon, Chad, Congo, DR Congo, Guinea, Mali, Niger, and Nigeria. We then imputed for all regions in each of these ten countries for all variables measuring structural change the averages from the 14 regions from the countries outside Sub-Saharan Africa. Importantly, we did not impute the values for child mortality and urbanization. Using the estimated regression coefficients from our empirical analysis, we then predicted the hypothetical TFR for each region and each country. For comparison, we also predicted the TFR using the actual levels of the structural change variables. We ran the prediction using three alternative specifications. All three predictions were based on the estimates from the SSA subsamples, since we are interested in predictions specifically for countries in SSA. However, the predictions differ regarding included indicators of structural change and thus samples used. Table 6 below shows the results from these simulations. Prediction 1 exploits the largest SSA sample (1b) and uses child mortality, urbanization, female education, female employment and nighttime light intensity as fertility predictors, and accounts for country-specific time-effects. The results from this prediction suggests that if the regions in the ten selected lagging countries had experienced the same structural change as the 14 most advanced regions outside SSA, their TFR would be 4.7 instead of 6.0, i.e. lower by 1.3 children or 21%. If we also account for region-fixed effects (Prediction 2), the predicted TFR is 4.28, even implying a difference of 1.72 children or 27%. Prediction 3 also includes insurance coverage as covariate, but relies on a smaller sample (2b) and fixed effects estimation is not feasible. Admittedly, with a range of 21 to 31%, the magnitude of the predicted fertility reductions is moderate, but they should be interpreted rather as lower-bound estimates, since the predictions keep child mortality and urbanization at the original level. An expansion of structural change is likely to go hand in hand with a significant decrease in child mortality rates and increased urbanization and hence even stronger fertility reductions. Overall, these simulations support the hypothesis that the absence of substantial structural change accounts for a sizeable share of the high levels of fertility observed in most countries of Sub-Saharan Africa.

Table 6: The effect of structural change on fertility, results from simulations

	Prediction 1		Prediction 2		Prediction 3	
	Mean	(Min – Max)	Mean	(Min – Max)	Mean	(Min – Max)
Observed TFR (w/o structural change) (1)	6.04	(3.21- 8.36)	6.04	(3.21 - 8.36)	6.04	(3.21 - 8.36)
Predicted TFR (w/o structural change) (2)	6.01	(2.99 - 8.23)	5.97	(3.23 - 8.37)	6.00	(2.86 - 8.38)
Predicted TFR	4.70	(2.36 - 6.07)	4.28	(2.22 - 6.86)	4.08	(1.68 - 5.60)

(with structural change) (3)					
Total difference (2)-(3)	1.31	(-0.15 - 2.54)	1.69	(-0.19 - 3.10)	1.92 (0.22 - 3.41)
Relative difference (2)-(3) / (2)	0.21	(-0.04 - 0.39)	0.27	(-0.05 - 0.54)	0.31 (0.05 - 0.53)
Sample	1b		1b		2b
Country-specific time trends	Yes		Yes		Yes
Region fixed effects	No		Yes		No

Notes: Predictions 1 and 2 are based on Sample 1b, Prediction 3 uses Sample 2b. All predictions account for country-specific time trends, Prediction 3 additionally for region-fixed effects. Predictions 1 and 2 include child mortality, urbanization, female education, female employment and nighttime light intensity as covariates; Prediction 3 also includes insurance coverage.

Source: Own calculations using data from DHS and LSMS (and analog) surveys.

### *Shorrocks Decomposition*

The results from the main analysis revealed a strong and robust negative relationship between the total fertility rate of a region and its degree of structural change. To provide some understanding of the contribution of the different aspects of structural change to the fertility transition, we used a Shorrocks decomposition (Shorrocks, 1982). Originally developed to decompose the factors contributing to income inequality, this method can also be applied more generally to estimate the relative contribution of different independent variables to a dependent variable's variance. The results from this analysis can for example help to prioritize alternative interventions in order to direct financial resources and efforts towards those areas where the impact on fertility is the highest; yet this decomposition is of course first of all a descriptive one and not a strictly causal one, also because the different components are correlated with each other.

We applied the Shorrocks decomposition to our preferred regressions from the main analysis, i.e. those models that include various indicators of structural change and control for country-specific time-effects. Table 7 presents the relative contribution of the grouped explanatory variables to the R-squared for selected specifications. Note that our controls, especially child mortality, contribute to a sizeable portion of the R-squared (about 14.4 to 17.7%). All indicators of structural change combined account for 34 to 38%, depending on the specification, of the R-squared, and the remaining share is captured by country-specific time-effects. Considering the indicators of structural change separately, female education is by far the largest contributor, accounting for 15.3 to 18.5% of the R-squared, followed by the female employment structure, accounting for 9.3 to 12.5%. The contribution of industrialization as proxied by nighttime light intensity is between 7.7 and 9.1% in the largest samples but drops below 4% in the smaller samples. Health insurance coverage contributes with 5.3% and even less in the African sample.

However, given the positive correlation between the share of non-agricultural formal jobs and health insurance, health insurance cannot absorb much more of the total variance.

Table 7: Results from a Shorrocks Decomposition: contribution of different aspects of structural change to the fertility transition.

	Sample 1a	Sample 1b (SSA)	Sample 2a	Sample 2b (SSA)
Child mortality	15.25 %	14.41%	17.71%	16.95 %
Urbanization	5.31%	8.88 %	5.58 %	7.87 %
Female education	15.29 %	16.95 %	18.49 %	17.68 %
Female employment	9.32 %	10.31 %	10.15 %	12.46 %
Nighttime light intensity	9.12 %	7.73 %	5.70 %	3.62 %
Country-specific time trends	45.71 %	41.71 %	42.37 %	41.42 %
Total R-squared	0.86	0.77	0.87	0.79
Child mortality			16.62 %	16.12 %
Urbanization			5.06 %	7.23 %
Female education			17.11 %	16.97 %
Female employment			9.71 %	12.03 %
Nighttime light intensity			5.67 %	3.45 %
Insurance coverage			5.32 %	2.88 %
Country-specific time trends			40.50 %	41.31 %
Total R-squared			0.87	0.80

Source: Own calculations using data from DHS and LSMS (and analog) surveys.

## 5. Conclusion

We built a unique data set of matched Demographic and Health Surveys and Household Income Surveys enriched with nighttime light intensity data from a large sample of low and middle income countries, including many countries in Sub-Saharan Africa. The data was matched at the regional level. To our knowledge, these data sources have never been matched before for such a large sample of countries at this level.

We use this rich dataset to explore the determinants of the fertility transition across the developing world and to identify in particular the role of structural economic change. Our key hypothesis is that, in line with unified growth theory, structural change is a key driver of the demographic transition.

Our regression analysis shows that post-primary female education, female employment in non-agricultural formal jobs, and industrialization as proxied by nighttime light intensity, and to a lower extent, higher female wages and health insurance coverage are indeed important drivers

of the fertility decline. Hence, the slow structural change or even its absence in many regions are indeed a key obstacle to the fertility transition.

Our simulations show that if countries in Sub-Saharan Africa with the highest fertility levels had experienced the same structural change as the most demographically advanced regions in our sample, fertility levels would be at most 69 to 79% of what they are now. A Shorrocks decomposition quantifies the share of the variance in regional fertility levels that can be explained by variables related to structural change at 34 to 38%.

Our results suggest that policies that enhance structural economic change could be a very effective trigger of the fertility transition in the Sub-Saharan African context. Such policies can include classical industrialization based on manufacturing as well as other industries and services like agro-business and the e-economy. Enhanced investment in education and health, labor market reforms that increase female labor market participation and women empowerment may accompany this process. Finally, access to formal insurance, which reduces the need for many children, can probably further push this transition. Family planning can help parents to achieve lower fertility goals, but we believe family planning alone is unlikely to play an important role in the absence of structural change.

Structural change needs to accelerate soon in Sub-Saharan Africa in order to turn the demographic burden that many countries increasingly experience into a demographic gift. The gift could arise if fertility rates eventually decline and hence a large work force coincides with a low dependency ratio. Bloom and Williamson (1998) have shown that this has been a substantial driver of the economic miracles in emerging Asia. Fertility rates that finally decline in a sustained way could further boost economic development and structural change through various channels so that the process could become self-perpetuating.

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