International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

Address: IIASA, Schlossplatz 1, A-2361 Laxenburg, Austria

Email: permissions@iiasa.ac.at

Working paper

Rural/urban fertility differentials in the Global South: Is female education the key driver of declining birth rates?

Saroja Adhikari (adhikaris@iiasa.ac.at)
Wolfgang Lutz (lutz@iiasa.ac.at)
Samir KC (kc@iiasa.ac.at)

WP-23-004

Approved by:

Anne Goujon
Program: Population and Just Societies
Date: 20 April 2023

Table of contents

ZVR 524808900

Disclaimer, funding acknowledgment, and copyright information:
IIASA Working Papers report on research carried out at IIASA and have received only limited review. Views or opinions expressed herein do not necessarily represent those of the institute, its National Member Organizations, or other organizations supporting the work.

The authors gratefully acknowledge funding from the European Research Council for the research project 'The Demography of Sustainable Human Wellbeing' (EmpoweredLifeYears/grant agreement No 741105).

Abstract

Over the past few decades, fertility has decreased in all regions of low- and middle-income countries, except for the rural areas in a few sub-Saharan African countries where the fertility transition has not yet started. The study of differentials in these fertility declines, draws on two quite independent bodies of literature, one demonstrating the impact of women's education on their reproductive choices and outcomes and the other focusing on rural/urban fertility differentials. Our research attempts to address both dimensions together and study their interactions. In particular, we investigate the hypothesis that rural/urban differences in the level of female education drive the apparent rural/urban differences in fertility and study how this pattern has changed over time. Using data from Demographic and Health Surveys (DHS), we study the trends in education-specific fertility in rural and urban regions of 36 low- and middle-income countries with surveys at different times. We also estimate a multi-level model of children born over the last five years at the individual level, pooling all existing DHS surveys and processing over 3 million individual data records. We find consistently strong education effects on fertility, which in most countries are stronger than the effects of place of residence (rural/urban). But individual-level education differentials do not fully explain the rural/urban fertility differentials, thus suggesting an additional place-of-residence effect. The resulting patterns can be directly used in multi-dimensional population projections by age, sex, level of education, and urban/rural residence, as is currently being attempted for the SSP (Shared Socioeconomic Pathways) scenarios widely used in the global climate change research community. The results of this first comprehensive study of rural/urban versus educational fertility differentials not only confirm the key role of female education in fertility decline but also suggest further in-depth research on the diffusion processes and environmental conditions that drive the remaining rural/urban fertility differentials among women with the same level of education.

Keywords: Fertility, rural, urban, fertility differentials, education, demographic and health surveys

About the authors

Saroja Adhikari is a researcher at the International Institute for Applied Systems Analysis (IIASA) (Contact: adhikaris@iiasa.ac.at)

Wolfgang Lutz is Interim Deputy Director General for Science at the International Institute for Applied Systems Analysis (IIASA). He is also the Founding Director of the Wittgenstein Centre for Demography and Global Human Capital (IIASA, OeAW, University of Vienna), and Professor of Demography at the Department of Demography, University of Vienna
(Contact: lutz@iiasa.ac.at)

Samir KC is a Research Scholar and Research Group Leader of the Multidimensional Demographic Modeling Research Group in the Population and Just Societies Program at IIASA (Contact: kc@iiasa.ac.at)

Acknowledgments

The authors gratefully acknowledge funding from the European Research Council for the research project 'The Demography of Sustainable Human Wellbeing' (EmpoweredLifeYears/grant agreement No 741105).

Introduction

Fertility has been declining globally at different rates across regions and socioeconomic groups. This is part of the universal process of demographic transition in which, typically, the decline in birth rates follows the decline in death rates, with the driver of both mainly being seen in general as "modernization" (Kirk, 1996). Much has been written over the past decades to gain a more specific understanding of what this rather vague traditional notion of modernization means. Explanations range from economic development to social development, including mass education, to changing mortality conditions and health services, including reproductive health. A recent comprehensive summary of the state of research on the drivers of the global demographic transition and its mortality and fertility components is given by Lutz (2021), who also introduces the notion of "cognition-driven demographic transition," which may hold the key to understanding the differences in fertility declines in different settings and is based on a different level of determination from cognitive to proximate determinants to social and economic determinants.

This complex multi-level determination of fertility plays out differently in different contexts. For this reason, even countries in comparable states of economic development can have different fertility levels and trends. Often, the experiences of regions within a country can also differ significantly in terms of the timing and magnitude of fertility declines, which can result in sizable fertility gaps between different regions of a given country (Pezzulo et al., 2021). The correlates for such variations between regions have been studied in many settings and times, and the potential roles of education and place of residence pointed out (Pezzulo et al., 2021; Cleland, 1996). However, there has not yet been a comprehensive empirical assessment of all available survey data considering education and rural/urban fertility differentials simultaneously and systemically. In this paper, we try to comprehensively assess the empirical evidence on this issue for all low- and middle-income countries where demographic and health survey data are available. We do so by studying the trends in fertility broken down by rural/urban place of residence and education categories over time for 36 countries, for which at least three surveys are available from 1990 to 2020. We also conduct multi-level analyses based on individual-level data for all available Demographic and Health Surveys (DHS) in 67 countries.

An important motivation for this kind of study is the immediate need for meaningful and defendable assumptions in the context of multi-dimensional population projections that go beyond the conventional age and sex projections and explicitly incorporate the levels of education and rural/urban place of residence now used widely in the Shared Socioeconomic Pathways (SSPs) in the context of climate change analysis (Jiang & O'Neill, 2017; Kc & Lutz, 2017). As will be discussed in more detail below, the models underlying these SSP scenarios are only three-dimensional with respect to age, sex, and level of education, while rural/urban place of residence is still modeled separately. This unsatisfactory situation is mainly based on the fact that, as yet, not enough is known about the interactions between the effects of place of residence and female education throughout the demographic transition (Jiang & O'Neill, 2018).

Empirical assessments of the fertility differentials by place of residence alone—without considering education—have often shown a U-shaped pattern. Beginning with the onset of the fertility transition in low- and middle-income countries, Lerch (2017) demonstrated an inverted U shaped pattern of the rural-to-urban fertility ratio over 40 years. The most plausible explanation for this pattern is that it results from the time lag between the rural and urban fertility transitions (Lerch, 2019). Urban areas were the first to experience a fertility decline, while stable fertility in rural areas caused the fertility gap to widen in the early phases of the transition. After some years, rural areas also entered the transition, and the rural–urban fertility gap began to narrow, even though the rate of decline was typically faster in urban areas. As the transition progresses, rural fertility decline picks up speed, and the rural/urban gap becomes narrower again, resulting in a three-stage inverted U-shaped pattern in the rural and urban fertility gap (Garenne & Joseph, 2002; Shapiro & Tambashe, 1999).

From a theoretical perspective, the fact that individuals' observable characteristics—such as, in our case, children born to women—vary among spatial units tells us little about the reasons for those differences. The differences in fertility between rural and urban areas can be caused by a whole array of factors: they can result either from a different composition of the population by relevant characteristics (such as level of education) or from environmental, economic, or social conditions that matter for fertility and differ from area to area. Plausible candidates for such conditions are, for instance, population density and the distance to the the closest service-delivery points for health and other relevant services, as well as the cost of housing, which also tends to differ greatly between urban and rural areas. Differing conditions can also result from the economic structure of the area. The typical dominance of agricultural activities in rural areas may result in a higher economic value for children, who can help on the family farm, and a lower opportunity cost for women who cannot take on outside employment. On top of this, there are many social and cultural factors that can lead to different family sizes being desired in rural and urban areas—and still many more factors that, together with those listed above, will jointly result in empirically observed rural/urban fertility differentials. Given this complex and still poorly understood pattern of fertility determination and the limits to reliable data on many of these aspects, we try to focus in this paper on one aspect that has received much attention in the analysis and has been well-established in its causal effect on fertility, namely individual-level female education. We try to identify which rural/urban differences are explained by this one factor, while viewing the rest as a still unexplained residual. In the remaining part of the introduction, we try to summarize the literature on the causal effect of education on fertility for individual-level fertility; this is followed by a discussion of the little-understood effects of community-level education through cultural diffusion processes.

Female education has long been acknowledged as a key driver of fertility decline, from the early declines in Europe in the 19th and early 20th centuries, to those in Latin America and Asia in the 1960s to 1980s, to those in Africa today. There is no room here to cover all the literature on this topic. Instead, we will indicate some recent literature summaries and new concepts that might help address this paper's research question. In terms of empirical associations, in a meta-analysis of 879 studies published between 1750 and 2006, Skirbekk (2008) found a consistently negative relationship between fertility and social status in terms of education over the study period. Regarding the theoretical foundations of this pervasive relationship, Lutz and Skirbekk (2014) provide a comprehensive summary of the scientific evidence of the effect of female education on fertility. This summary also explicitly deals with the complex issue of causality and establishes that there is indeed a functional causality between increased female education and lowered desired family size; this encompasses empowering women to access contraception, strengthening their role vis-a-vis their partner, breaking with traditional norms and making other changes needed to actually achieve the desired family size.

In terms of the specific mechanisms by which female education affects fertility levels at different levels of education, Lutz (2021) has pointed out the cognitive empowerment that is associated with basic literacy and numeracy and brings women to move their reproductive behaviour from a fatalistic to a more planning attitude so as to bring fertility "within the calculus of conscious choice," to cite the first of the three famous pre-conditions defined by Ansley Coale (1973) . This decisive cognitive pre-condition for the onset of the fertility transition led Lutz (2021) to speak of a cognition-driven demographic transition. The second pre-condition, listed by Coale refers to economic costs and benefits—where women with higher education have higher opportunity costs and also typically want to be able to offer their children a better life, including better education which is all associated with costs. The third pre-condition has to do with the availability of accessible means of family limitation (i.e., essentially modern contraception). Here again, more educated women are shown to have better information and to be more willing to overcome traditional values. Hence. this literature makes it clear that education changes not only the socioeconomic standing of people but also the degree of rationality in their behavioral choices and the changes in their value systems, including what economists call the "quantity–quality" trade-offs (i.e., women wanting fewer children who will have a better life). Hence, when it comes to fertility-related behavior, this cognitive level of degree of rationality and value changes interacts with the level of changing social and economic conditions and, as an important third level, with what Bongaarts (1987) calls the proximate determinants of fertility. These three levels of determination all matter (Lutz, 2022) and, in particular, the cognitive level shows interesting patterns of innovation and diffusion that are potentially relevant for a better understanding of the rural/urban differentials addressed in this paper.

A body of literature on the diffusion of ideas and behaviors goes far beyond differentiated demographic trends. According to the "diffusion of innovation" theory, attitudes and behaviors that are initially rare or absent in the population become more common within a graduated process (Rogers,1995). A newly innovated or introduced behavior become more common over time as different groups of people adopt the same behavior. As Rogers (2003) suggested, such people fall into five groups: The first group of innovators (2.5%) are usually members of a higher social stratum and willing to take risks while generating new ideas. The second group is that of early adopters (13.5%), who are the most open to new ideas, well-educated, and have the highest level of social influence. The early majority (34%) is in contact with the early adopters but takes longer to accept the innovation than the early adopters. The late majority (34%) and laggards (16%)

are the last to adopt new ideas. They are usually from a lower socioeconomic class, have little or no political influence, and also have a lower education level.

In the field of fertility decline, there has been a long tradition of studying diffusion processes: this started with the Princeton European Fertility Project, which concluded the diffusion of family limitation prctice was innovative behavior that triggered the fertility decline in historical European populations that contributed to fertility decline in historical European populations (Knodel & van de Walle, 1979). In an authoritative synthesis by the National Research Council (2001) entitled "Diffusion Processes and the Fertility Transition," Casterline stresses that arguments classified as "diffusion theories" tend to vary in what they regard as the specific causal contribution of diffusion theory. That author also stresses that the diffusion argument does not provide a sufficient foundation for a theory of fertility change because it fails to explain why individuals change their reproductive behavior and why certain innovations are accepted and others are not. He also assesses that most of the studies in the field focus more on how diffusion occurs rather than what actually diffuses. There have also been a growing number of empirical studies on social networks and associated social learning that—above and beyond their contributions to social theories—have also aimed at applications in the design of effective family planning programs in higher fertility settings.

Education expansion occurs in tandem with the demographic transition (Goujon, 2008). During the transition, differences in fertility among or within countries could be linked to educational expansion (Lutz & Kc, 2011). Education has continuously expanded in low and middle-income countries in the last decades. In the 1990s, the average years of schooling were 3.8 years in Africa, 5.9 years in Asia and 6.4 years in Latin America and the Caribbean (LAC), which by the 2010s increased to 6.2, 8, and 8.5 years, respectively (Lutz et al., 2018). Similarly to fertility, the pace of educational expansion varies across countries and between the rural and urban areas within a country. According to the World Bank, urban people in lower- and middle-income countries have significantly higher education levels than rural people (Filmer et al., 2018) . These urban–rural educational disparities can arise for several reasons. Access to education at all levels is typically better in urban areas, and the gaps are particularly large for secondary and higher education. Intergenerational transmission can also contribute to lower educational aspirations among the (less-educated parents of) rural children (Sánchez & Singh, 2018). Poor families have fewer resources to invest in their children's education, and additional barriers can arise in remote areas that prevent school attendance and continuation into higher education (Hughes, 2018). Better opportunities for adequate employment mean that those who left rural areas for higher education in the cities would settle in cities and hardly ever return to the rural areas. The current migration trend shows a significant rural-to-urban migration rate among educated people (both men and women) (Browne, 2017), also contributing to a higher proportion of educated people in urban areas.

Research Question

The starting point of this study is the assumption that educational expansion and urbanization are dynamic processes that influence each other and are jointly associated with the speed of the fertility transition in rural and urban areas within a country. So far, there have been independent assessments of the patterns of educational differences over this transition, as well as of the rural/urban differentials, as described above. Still missing, however, is a comprehensive empirical assessment of changes that jointly address both differentials. In other words, we want to better understand the differentials by education, considering rural and urban populations separately, what the rural/urban differentials are within specific educational categories, and how these patterns change over time. This leads to **the question of what matters more for fertility: place of residence or female education**? This also has important policy implications as well as implications for population forecasting.

Gaining relevant insights for multi-dimensional population forecasting has also been the primary motivation for this study. In the context of further improving the "human core," that is, the multi-dimensional population projections by age, sex, and level of education, underlying the SSP (Shared Socioeconomic Pathways) scenarios that have become the dominant and most frequently cited socioeconomic scenarios in the field of climate change analysis (O'Neill et al., 2017), a next step is to cross-classify these three demographic dimensions with rural/urban place of residence as a fourth dimension. In their current form, the SSPs provide integrated multi-dimensional population scenarios by age, sex, and level of education for all countries to 2100, which also reflect the well-established patterns of education differentials in fertility and mortality trends where fertility and mortality rates are consistently lower for more educated people than for less educated people (Lutz et al., 2014). In addition, each of the SSPs is associated with certain trends in urbanization, which are derived from models based on the UN global urbanization projections (Jiang & O'Neill, 2017). These urbanization projections, however, only give the proportion of the total population of each country that lives in urban versus rural areas without providing the age distributions of these populations; they do not provide breakdowns by sex and level of education. In other words, currently, the SSPs give, on the one hand, scenarios for proportions rural/urban and, on the other, independent scenarios for populations by age, sex, and level of education. This situation is unsatisfactory from a theoretical point of view because age, sex, place of residence and education level are all relevant human characteristics that tend to vary together and conceptually can thus be jointly modeled by existing methods of multi-dimensional population projections (Lutz, 2021). It is also unsatisfactory from a practical user's perspective because for downscaling the SSPs from national to sub-national level requires information by age, sex, and level of education cross-classified by place of residence. The feasibility of such a 4-dimensional population approach has already been demonstrated in an application to India and its individual states, rural/urban places of residence, education, age, and sex (Kc et al., 2018). But for a global-level application not enough is yet known about the patterns of fertility and mortality change and their differentials when education and rural/urban are being simultaneously considered in the model. This paper presents a step in the direction of systematically exploring the differences and interactions between educational and rural/urban fertility differentials and their trends over time for all low- and middle-income countries for which a series of representative surveys are available.

Hypothesis

Women's education consistently has a negative impact on fertility over the course of the demographic transition, but it is unlikely to be the only factor causing rural/urban fertility differences. Previous research has found that women in rural areas have more children than women in urban areas. Considering the higher concentration of higher-educated women in urban areas together with the lower fertility rate among higher-educated women, we study the hypothesis that the lower fertility in urban areas is, to a large extent, explained by this composition effect.

Data and Methods

The empirical analysis presented in this paper is in two parts based on large numbers of DHS surveys. In the first part, we use data from 36 countries, as listed in table 1, which have at least three surveys collected between 1990 and 2020 for the analysis of aggregate level trends in TFR (Total Fertility Rate) cross-classified by education and rural/urban place of residence. In the second part, we use all DHS surveys available (including also countries with only one or two surveys) to study the relative importance of education and place of residence for fertility at the level of individual women.

The standard DHS survey is the only one that provides comprehensive information on reproductive health, individual fertility history behavior, and various relevant social and economic variables in low- and middle-income countries. DHS aims at five-year intervals between surveys, but such regular intervals have not been possible for all countries, and as a consequence, not all countries have the same kind of time series of surveys. For this study, we could use a total of 179 sets of DHS data for 36 countries. For each of these countries, we have between 3 and 9 data sets for our study period 1990–2020. We considered only those countries for which at least three waves of DHS data were available and that had a national TFR (Total Fertility Rate) of 2.0 or higher in 2017. We estimated the TFR from the DHS data for each country, survey year, rural and urban location, and four education categories (no education, primary, secondary, and higher). To simplify the analysis and match the dichotomy of rural/urban for the analysis, we collapsed these four categories into two: lower education (no education or primary) and higher education (secondary and higher).

Table 1: List of countries and DHS survey years used for the aggregate level analysis

Country	Demographic and health survey years								
Bangladesh	1993	1996	2004	1999	2007	2011	2014	2017	
Benin	1996	2001	2006	2011	2017				
Bolivia	1994	1998	2003	2008					
Burkina Faso	1993	1998	2010						
Cameroon	1991	1998	2004	2011	2018				
Chad	1996	2004	2014						
Colombia	1995	2000	2005	2010	2015				
Cote d'Ivoire	1994	1998	2011						
Egypt	1992	1995	2000	2003	2008	2005	2014		
Ethiopia	2000	2005	2011	2016	2019				
Ghana	1993	1998	2003	2008	2014				
Guatemala	1995	1998	2014						
Guinea	1999	2005	2012	2018					
Haiti	1994	2005	2012	2016					
India	1992	1998	2005	2015					
Indonesia	1991	1994	1997	2002	2007	2012	2017		
Jordan	1990	1997	2002	2007	2009	2012	2017		
Kenya	1993	1998	2003	2008	2014				
Lesotho	2004	2009	2014						
Malawi	1992	2000	2010	2015					
Mali	1995	2001	2006	2012	2018				
Mozambique	1997	2003	2011						
Nepal	1996	2001	2006	2011	2016				
Niger	1992	1998	2006	2012					
Nigeria	1990	2003	2008	2013	2018				
Pakistan	1990	2006	2012	2017					
Peru	1991	1996	2000	2010	2011	2012			
Philippines	1993	1998	2008	2013	2017				
Rwanda	1992	2000	2005	2007	2010	2014	2019		
Senegal	1992	1997	2005	2010	2012	2015	2017	2018	2020
Sierra Leone	2008	2013	2019						
Tanzania	1991	1996	1999	2004	2010	2015			
Turkey	1993	1998	2003	2008	2013				
Uganda	1995	2000	2006	2016					
Zambia	1992	1996	2001	2007	2013	2018			
Zimbabwe	1994	1999	2005	2010	2015				

In the following analysis, we first study the average TFRs in sub-groups of women differentiated by level of education and place of residence for each country and year, while in the multi-level analysis in the second part, we use all individual records of all samples combined, as will be indicated. For the multi-level analysis, we used 202 available datasets from 1986 to 2020 for 63 countries. Of these, 36 countries are from Africa, 17 from Asia, and 10 from Latin America and the Caribbean. The list of countries and survey years used in the multi-level analysis is provided in Appendix B.

For the aggregate-level analysis of the sub-population of women, we face the problem that, especially in the high education categories of rural regions, the number of cases in each cell can get very small. Because of this, we found that the confidence intervals of the estimated TFRs become unacceptably wide if the sample size was below 100. For this reason, we estimated TFRs only when the cell size had at least 100 women, as we found that the cut-off of 100 women was sufficient to avoid bias.

We used the existing "DHS.rates" software package in R (Elkasabi, 2021) to estimate the TFRs of women in each of the cells for the 36 months before the survey. The difference in fertility levels between rural and urban regions, as well as the different education categories, are mostly assessed in terms of the absolute differences in TFR, which is calculated by subtracting lower TFR (urban, higher education) from the higher TFR (rural, lower education). Fertility differences are computed for every country, each survey year, and each education group. Similarly, the educational differential in fertility is calculated by subtracting "lower education" TFR from "higher education" TFR.

To further examine the impact of education and rural/urban place of residence on individual-level fertility behavior, we used a multi-level Poisson regression analysis using 202 DHS datasets collected between 1986 and 2020 with more than three million ever-married women.

Study variables

Dependent variable: Our study analyzed the effect of education and place of residence on fertility. Fertility, the dependent variable of this study, is the number of live births a woman has had within the last five years from the date of interview in DHS.

Independent variables: The variables of interest in this study are the education level of women, which is categorized into four groups (aggreagated into two groups while estimating TFRs as mentioned above), and place of residence, which is classified as either rural or urban. To see the effect of education on the fertility behavior of women living in different environments, namely in rural or urban settings, we have also extended the model to include the interaction term of education and place of residence. In addition, we used the age of the women at the time of the interview in the DHS and the survey period (five years interval) of each DHS data set starting from 1985–1989 as the control variable.

The multi-level logistic regression model is used to study the influence of independent variables on fertility. The multi-level regression model is popular among geographers as it can measure the extent and nature of spatial variation in individual data. For hierarchical data, the multi-level model can control for bias due to unobserved heterogeneity arising from similar traits shared by individuals within a group (Morselli, 2017; Raudenbush & Bryk, 2002). DHS data is hierarchical, and our data had two levels where individual women (first level) were nested within the country (second level). We calculated intra-class correlation (ICC) to see the variability between the fertility behaviors of women living in the same country. We observed that the ICC for the country is quite high (0.3), indicating less variability in fertility behaviors among women living in the same country. We therefore chose a multi-level regression model to control for bias, as women in the same country shared similar characteristics. The model with three predictor variables and interaction terms is specified as follows:

$$log\ (\text{Births}_{i,j}) = \beta_{0j} + \beta 1\ \text{age} + \beta 2\ \text{survey period} + \beta 3\ \text{place of residence} + \beta 4\ \text{Education}\ + (\text{Edu} * \text{urban})\sigma + \epsilon_{ij} \quad \ldots\ldots (1)$$

Where i is individual observation/woman and j is individual country ranges as j= 1,…..,63.

β_{0j} is the random intercept for each country, model (1) can also be written as

$$log\ (\text{Births}_{i,j}) = \beta_0 + \beta 1\ \text{age} + \beta 2\ \text{survey period} + \beta 3\ \text{place of residence} + \beta 4\ \text{Education} + (\text{Edu} * \text{urban})\sigma + u_{0j} + \epsilon_{ij} \quad \ldots\ldots (2)$$

The response variable in the model is denoted by Births_{ij}, which means the number of live births given within the last five years from the date of interview in DHS by i^{th} ever married women living in j^{th} country.

β_0 is the predicted average number of live births given by women within five years, while all other predictors have base/reference values.

$\beta 1, \beta 2, \beta 3,$ and $\beta 4$ are the coefficients for age, survey period, place of residence (rural a reference category) and education, respectively.

σ indicates the interaction coefficients between the place of residence and education.

u_{0j} is a random part added in the random intercept, i.e, $\beta_{0j=}\ \beta_{0\,+}\ u_{0j}$

The regression analysis is performed separately for Africa, Asia, and LAC. We also ran a model for all regions by combining the data from all three regions together.

We used the same country-specific definition of DHS data for the urban and rural regions, which is a limitation of this study. These country-specific definitions have been changing over the periods in different countries. Because the definition of urban and rural areas evolved through time, comparisons of results from different periods and between nations can be biased. For example, the term "urban" is frequently redefined in Nepal. Urban areas were defined as having over 5,000 residents in 1950. In 1992, this criterion was changed to 20,000 population, basic urban infrastructure (determined by the government), and one million (Nepalese rupees) revenue. It was changed again in 1999 to 20,000 people for Terai and 10,000 for Hill and Mountain regions, with minimum urban facilities and annual revenue of NRs 5 million for Terai and NRs 500,000 for Hill and Mountain regions (Chapagain, 2018). However, urban areas have always had better education, health, and other developmental (transportation, housing, access to information) facilities, which influences women's behavior in such places.

Results

In aggregate level analysis, the TFR trends over time are tabulated separately for four population sub-groups: rural women with high and low education and urban women with high and low education. These fertility trends together with the rural, urban, and national totals, are listed for all countries in the Appendix table A. Figure 1 below highlights four different patterns of trends from four different parts of the world. In each case, the dotted black line shows the trend in the national TFR, while the other lines show the trends in the urban and rural totals as compared to those in the high (highedu) and low (lowedu) education totals. The first pattern is that of Nigeria, where there are very clear fertility differentials between the different sub-populations, all of them at a comparatively high level and with only marginal declines over time. The fertility of women with no or low education actually seems to have increased somewhat between 1990 and 2010, when it reached around seven children per woman before starting to decline to its 1990 level of 6.5 in the most recent survey. This is reflective of what in the literature has been discussed as the "stalled African fertility decline" (Kebede et al., 2019). The fertility of urban women or those with higher education is consistently lower at a level of 4–5 children but also shows little change over time. The overall decline in national level TFR from 6 to slightly above 5 thus mostly results from the changing educational composition of the population over time, with the group of more educated women gradually increasing in the younger cohorts and thus gaining more weight in the national total.

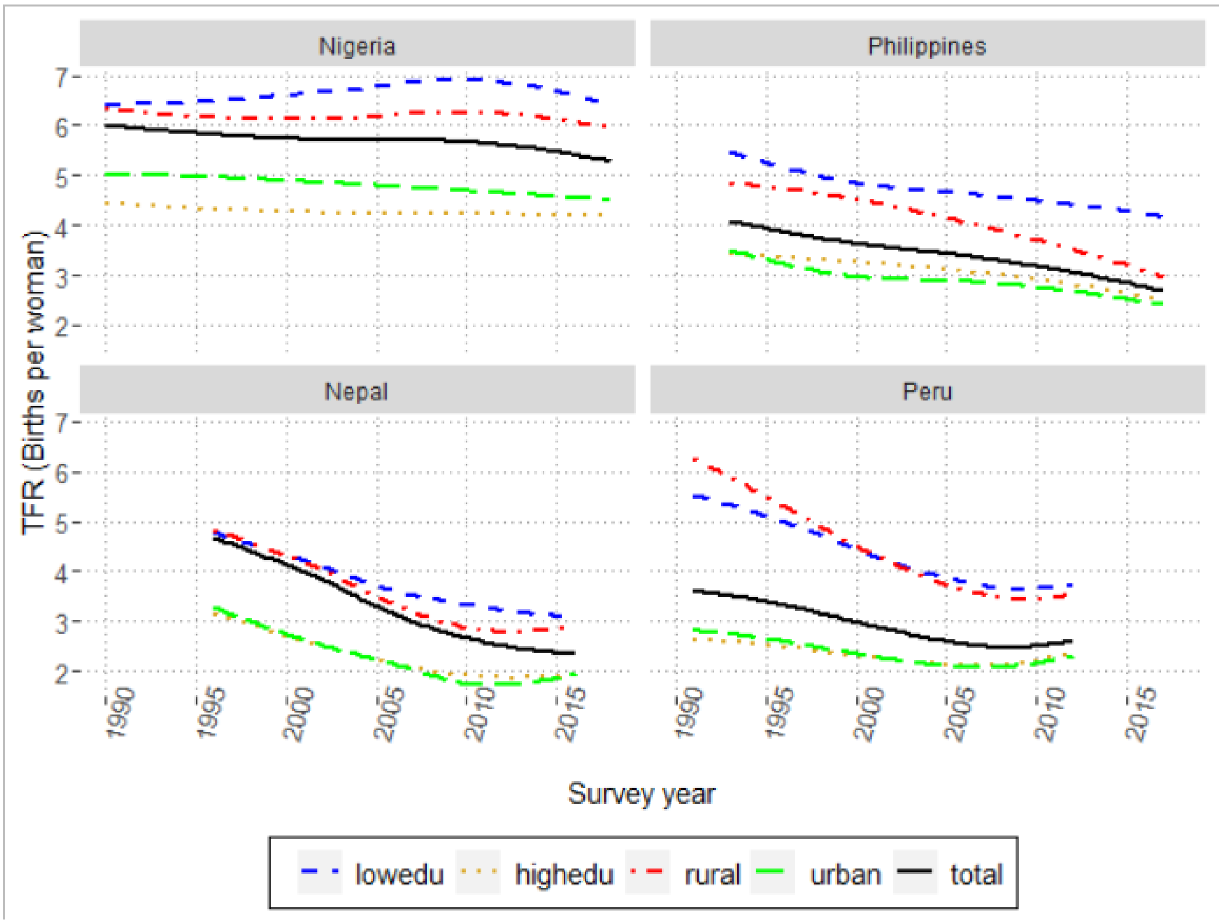

Figure 1: Trends in differentiated TFR between education and place of residence

The Philippines shows a different pattern in which the fertility of all sub-populations gradually declines over time. The differentials are much higher among education groups than between rural and urban women. In particular, rural fertility declined quite steeply over the last two decades, while the fertility of low-educated women remained rather high. This is presumably due to progress in spreading universal schooling into rural areas. Except for the remaining women with low education, all subgroups now have TFRs below 3. This differs from the pattern of decline in Peru, where the decline has been steeper until a recent leveling off, and the low education-rural and high education-urban trends are much more closely associated. It reflects a more divided national population largely along presumably ethnic differences, with indigenous populations being mostly in the rural areas and with lower education.

Finally, the pattern in Nepal is quite similar to that in Peru in terms of the trends of the different subpopulations. The main difference, though, is the continued decline in aggregate national TFR which can only result from the fact that over time the share of urban and more educated women has been increasing substantially. While in Nepal today, more educated and urban women already have below-replacement level fertility, even though the national level fertility has fallen to 2.3.

Figure 2 summarizes the evolution of these differentials for the same four countries depicted in Figure 1. It shows the trends in the absolute differences between rural and urban as well as low and high education groups. In all four countries, the education differences are bigger than the place of residence differentials, at least after 2000. While in Nigeria, they actually increase over time, in Peru, they both have a declining trend and are very similar to each other. In the Philippines, on the other hand, the trends diverge over time, with the rural/urban differential diminishing while the education differential stays constant. These very different patterns of trends in fertility differentials over time already indicate that there is unlikely to be a global pattern of change in the differentials as countries progress in their demographic transitions.

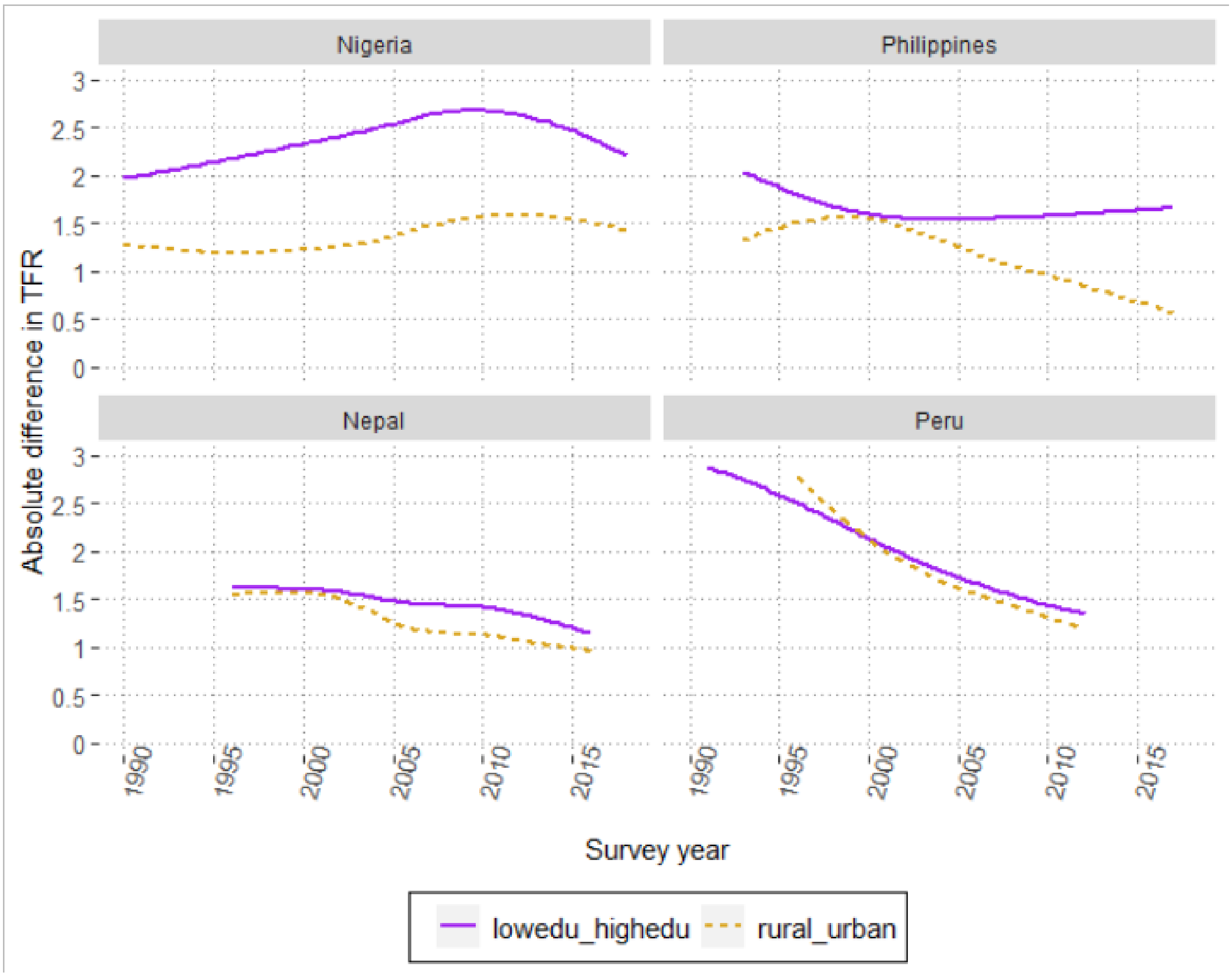

Figure 2: Trends in relative differential by levels of education & place of residence

Figure 3 then plots the global pattern of rural/urban differentials based on all 37 countries included in the aggregate level analysis (as listed in Table 1 above). It shows the absolute differences between rural and urban TFRs for each country and the point in time on the y-axis sorted by the level of urban TFR on the X-axis. As, in the original dataset, we have four different levels of educational attainment, and they were only dichotomized in the above-discussed analysis to improve it vis-à-vis the dichotomous rural/urban classification, this figure now shows the pattern of four education categories separately. The four curves have been fitted to the respective data points. The fact that the resulting curves for women without any education and those with primary education are very similar, with the same being the case for women with secondary and higher education, shows that the aggregation into the two education categories used above makes sense. If the level of urban TFR used on the x-axis is assumed to be reflective of the stage of demographic transition, then the resulting U-shapes of the curves confirm the above-described overall pattern, as suggested by Lerch (2017). It implies that at intermediate levels of fertility (e.g., mid-way in the fertility transition) the rural/urban differentials tend to be highest, whereas they are lower both on the high and low ends of the process. The pattern by the level of education also shows that rural/urban differences in TFR are only about half the size for more educated women than those appearing for less educated women who universally have higher levels of TFR. In our search for generalizable patterns of joint rural/urban and education differentials that can be used for informing the fertility assumptions in multi-dimensional population projections, this can at least provide some tentative guidance, as will be discussed below.

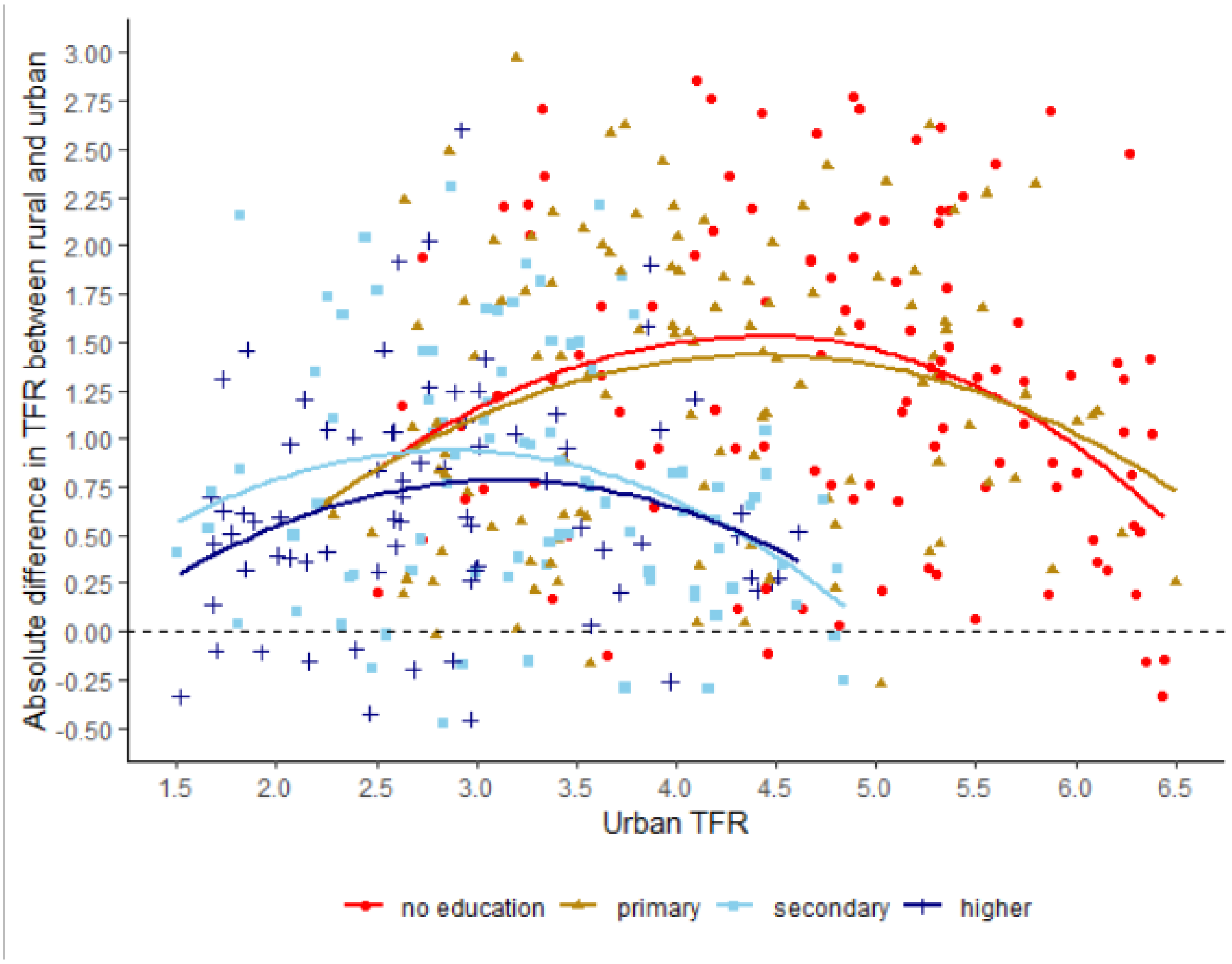

Figure 3: Global pattern of urban/rural differentials by the level of education (four categories) from 1990 to 2020

To provide still deeper insight into the determination of fertility jointly by place of residence and education, the second part of our empirical analysis estimated individual-level effects of these two dimensions for a data set including all available DHS surveys, thus covering over 3 million individual women. The results are presented in Table 2 by world's region separately and for all regions together. For both demographic dimensions, the categories with the highest fertility (rural and no education) are taken as the reference category. As described in the methods section above, the dependent variable is the usual indicator of period fertility used in DHS-based studies, namely the number of children born within the last five years, with the relative effects of place of residence and education being estimated after controlling for country, survey year, and age of the woman. While Table 2 gives the numerical estimates, Figures 4–7 translate them into predicted period fertility levels for women belonging to different education and place of residence groups for Africa, Asia (south and southeast Asia), Latin America & the Caribbean, and all regions together.

Table2: Multi-level regression results

Fertility indicator: Children born per woman within the last five years from a survey among ever-married women of age 15–49, controlled for countries, survey period, and age of women				
Predictors	**Africa RR (95% CI)**	**Asia RR (95% CI)**	**LAC RR (95% CI)**	**All regions RR (95% CI)**
Intercept	1.278***(1.218-1.340)	1.400***(1.217-1.611)	2.287***(2.111-2.478)	1.44***(1.360-1.531)
Survey period	0.986*** (0.984-0.987)	0.971***(0. 970-0.972)	0.918*** (0.916-0.921)	0.970***(0.970-0.971)
Place of residence: rural (ref)				
urban	0.857***(0.850-0.862)	0.891***(0.883-0.889)	0.719***(0.701-0.737)	0.865***(0.861-0.870)
Education: no education (ref)				
primary	0.967***(0.961-0.971)	0.907***(0.901-0.913)	0.794***(0.783-0.804)	0.941***(0.937-0.945)
secondary	0.880***(0.873-0.887)	0.891***(0.885-0.897)	0.656***(0.645-0.667)	0.883***(0.879-0.887)
higher	0.756***(0.739-0.774)	0.876***(0.867-0.887)	0.576***(0.557-0.595)	0.837***(0.829-0.846)
Interaction effect				
urban*primary	0.948***(0.940-0.960)	0.970***(0.957-0.983)	1.065***(1.037-1.095)	0.947***(0.940-0.954)
urban*secondary	0.951***(0.941-0.962)	0.984* (0.973-0.995)	1.167*** (1.135-1.201)	0.961***(0.954-0.968)
urban*higher	1.022 (0.998-1.051)	1.014 (0.998-1.030)	1.248*** (1.198-1.300)	0.982**(0.970-0.994)
R square				
fixed effect	0.21	0.41	0.36	0.35
Number of countries	36	17	10	63
Number of DHS data sets	119	53	30	202
Sample size	1115005	1498702	470523	3084230

Notes: *** p<0.001, **p<0.01,* p<0.05, ˙ p<0.1

The numerical values in Table 2 show that both differentials are strongest in the DHS countries in Latin America. As Figure 7 shows, this is particularly so for education differentials in rural areas. In those rural areas, women with higher education are estimated to have less than half the period fertility level of women without formal education. The differentials are still clearly visible and in the expected order but are less pronounced in urban areas.

In Africa, the education differentials are very strong both in rural and urban areas, with urban fertility consistently being lower for each education category. Urban women without any formal education have roughly the same level of period fertility as rural women with some secondary education. In Asia, the rural/urban difference is still less pronounced, and these urban women without formal education still have higher fertility than rural women with some secondary education. Moreover, in Asia, the fertility of women with higher education is only marginally lower in urban areas as compared to rural ones.

The African pattern dominates the pattern of all surveys from all regions pooled together, partly because the largest number of DHS surveys was conducted in Africa. The pattern of education differentials is very pronounced and almost linear from the no education to the higher education groups for both rural and urban women. But the line in urban areas is shifted downward by about less than 0.2 children per woman.

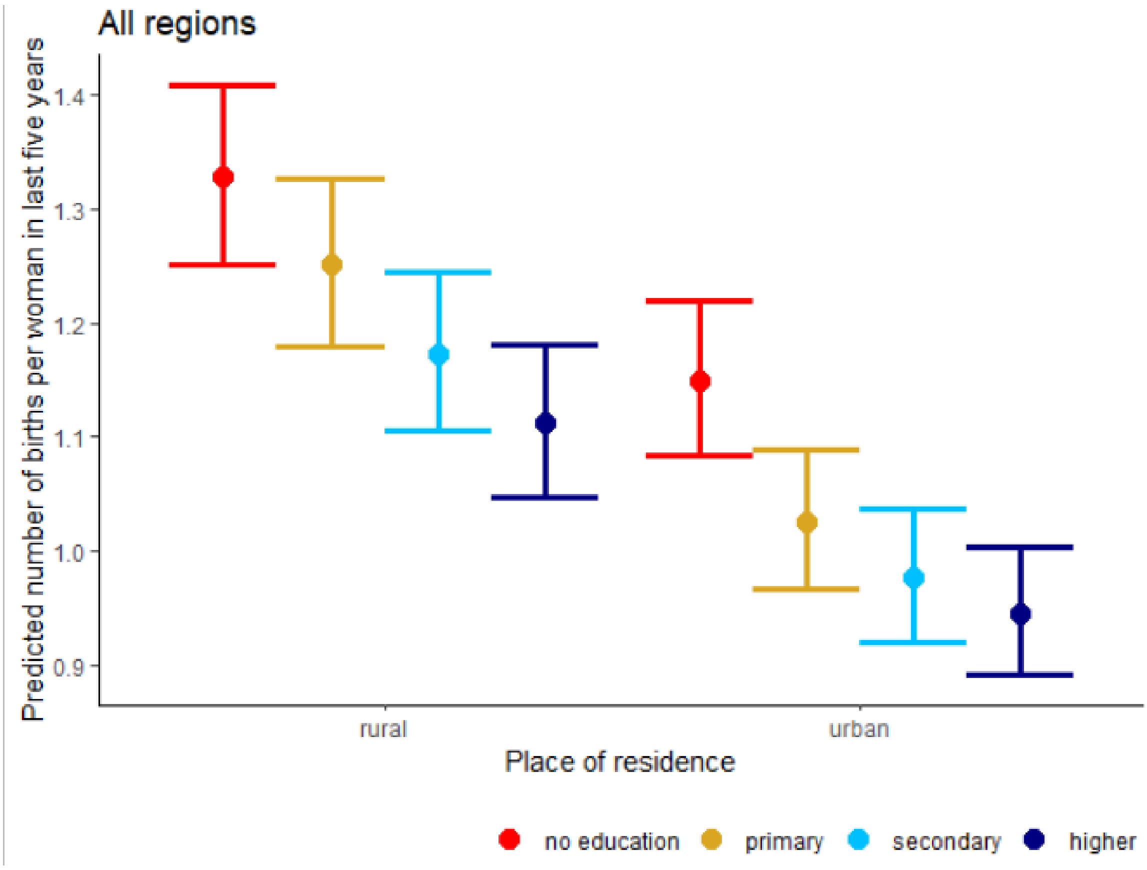

Figure 4: Predicted number of live births per woman within five years: all regions

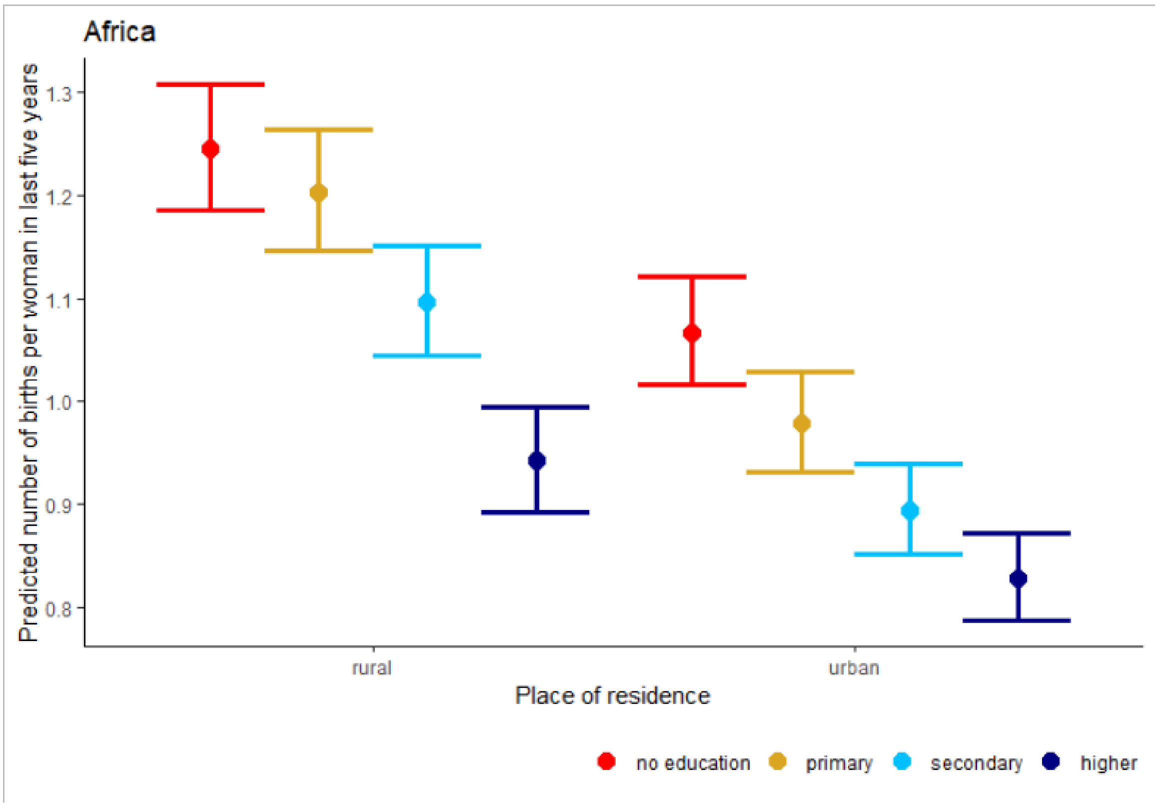

Figure 5: Predicted number of live births per woman within five years: Africa

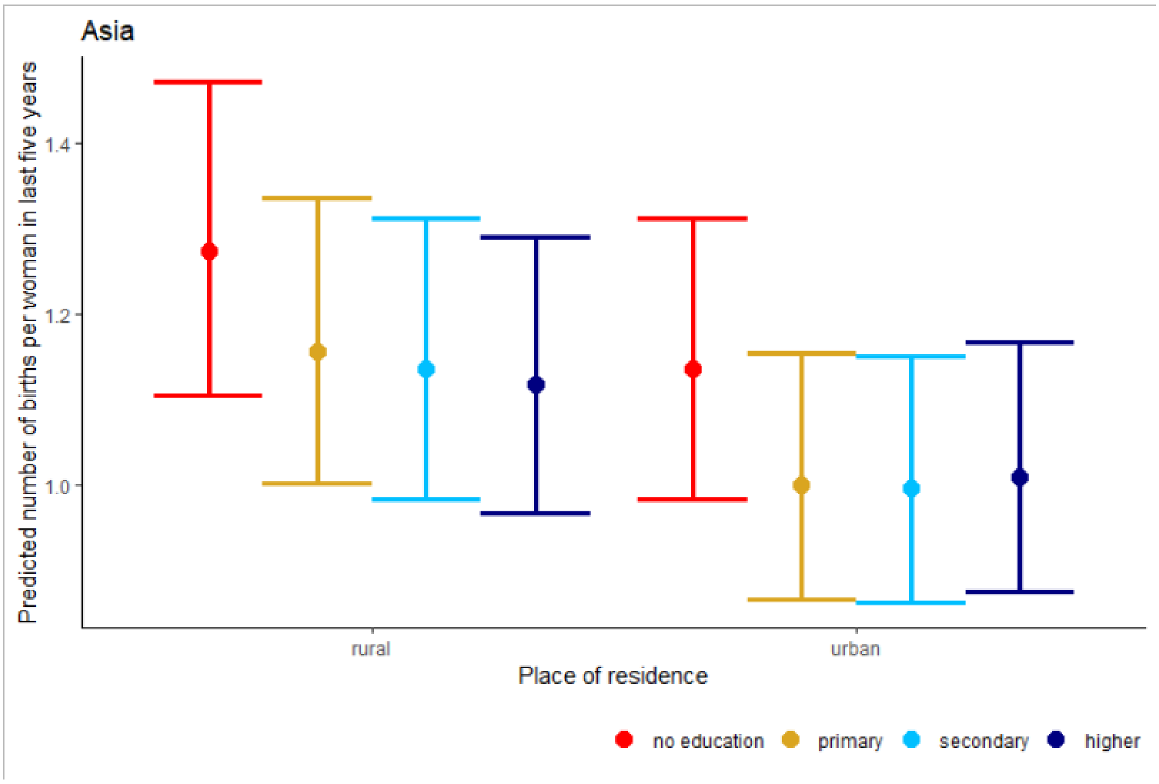

Figure 6: Predicted number of live births per woman within five years: Asia

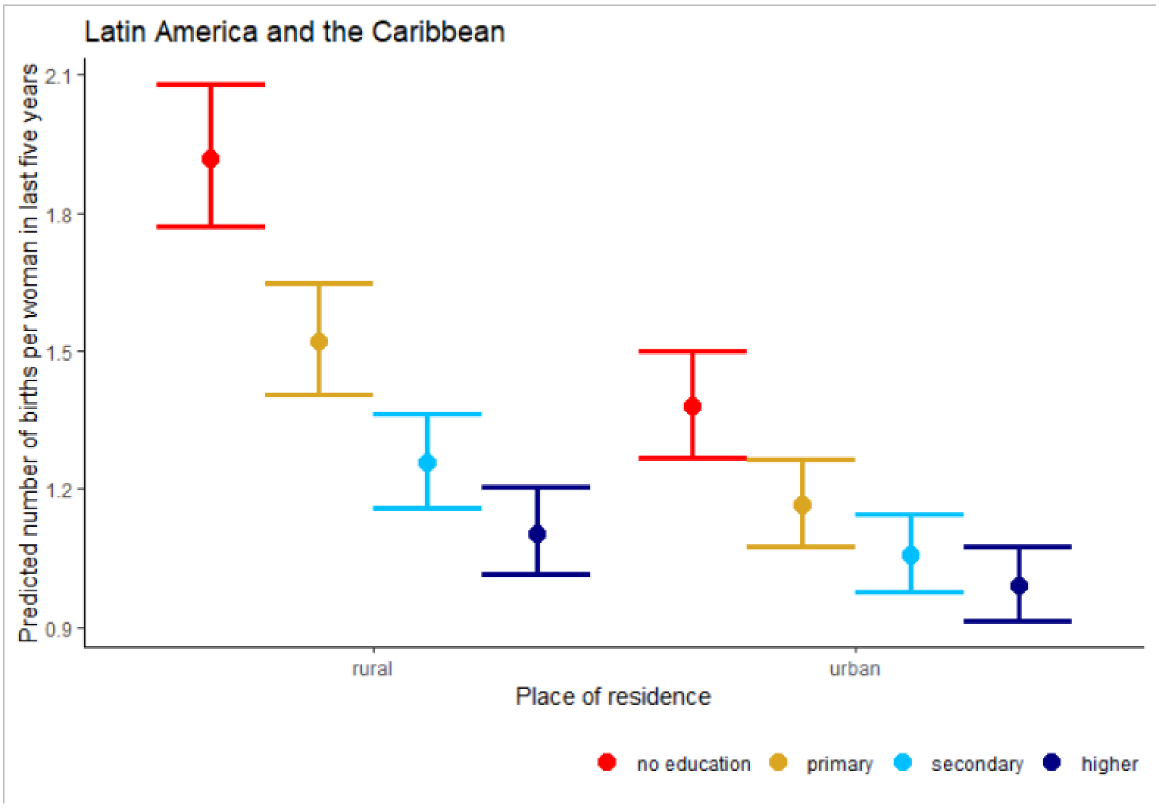

Figure 7: Predicted number of live births per woman within five years: LAC

The interaction effect in Table 2 shows an additional effect of place of residence on top of the effect of education on fertility. We infer that the additional effect of place of residence violates our hypothesis. In Asia and Africa, women living in urban areas additionally have an lower risk of having a child than women living in rural areas with a similar level of education. However, until women reach higher education, this additional residence effect decreases and then starts to increase with an insignificant positive effect on fertility (around a 2% increase in the risk of having an additional child) if women live in urban areas. In the case of LAC, the independent effect of urban places of residence and education is negative and stronger in terms of the risk of women having an additional child . However, an additional effect of an urban place of residence is positive to the risk of having an additional child compared to the rural one. This effect increases with increasing educational levels.

Viewed together, this rich individual-level analysis confirms the pattern already identified in the aggregate-level analysis above. In all individual countries, as well as in regional country groupings and over time, there is a very strong and dominant education effect. This is the case for the dichotomous education variable as well as for the one with four education categories, where the differentials tend to show an almost inverted shaped pattern from the lowest to the highest category. On top of this, there is a strong place of residence effect which results in consistently lower fertility in urban areas for women of all education levels. In addition, the effect of place of residence differs in magnitude and direction based on women's education and the stage of the national fertility transition. Thus, in a nutshell, the conclusion is that both education and place of residence matter for fertility levels. Alternatively, in other words, the rural/urban fertility differentials that are apparent in the one-dimensional perspective along the place of residence are partly explained by the substantial education differentials together with the fact that urban women tend to be better educated than rural ones. However, even after accounting for this education effect, there remains a strong and independent place-of-residence effect.

Conclusions and Outlook

Where do these findings leave us with respect to the research question asked in this paper?
The primary research question was to gain insights into how to project fertility levels in the context of multi-dimensional population projection models considering age, sex, level of education, and rural/urban place of residence. The widespread use of the existing SSP scenarios for many different kinds of studies in the context of climate change testified to the large demand for population scenarios that specify where people live—including urban and rural populations (Dunne, 2022; Zeleňáková et al., 2015)and what their levels of education are so that their capabilities for both climate change mitigation and adaptation can be assessed (Anderson, 2010, 2012). But as described above, the current SSPs do not yet fully integrate the dimensions of education and place of residence in a truly multi-dimensional model. So far, in the global projections for all countries, the projections of urban proportions are carried out independently from the projections by age, sex, and level of education (Kc et al., 2018; Ritchie & Roser, 2018). A key prerequisite for being able to merge them is to allow the joint determination of fertility by the level of education and place of residence to be better understood. The analysis presented in this paper has provided eight important insights that are directly applicable to the design of the multi-dimensional model.

The most important conclusion of this study is that in the context of projections, both education and place-of-residence differentials need to be considered. Despite the apparent correlation between more education and urbanization, it is not justified to assume that explicitly considering rural/urban places of residence also automatically captures the education differentials, or vice versa. The model needs to be based on assuming education differentials and, as well as this, place-of-residence differentials that apply to each education group. The numerical results of the analysis presented here also give us a useful numerical basis for the strengths of differentials to be assumed in projections for different world regions.

In addition to the helpful information about the differentials' magnitude at any given time, the analysis of the time trends in the first part of the study also provides us with useful information about the changing magnitude of the differential over the course of the fertility transition. Here the resulting U-shaped pattern can be applied with the additional information that the absolute differences are bigger for lower education groups than for the higher ones. In this respect, the study has provided a useful empirical basis for defining the scenario assumptions for the future.

A secondary, more complex research question was to better understand the different fertility determination processes that are due to the level of education a woman has and where she lives. The significant negative to insignificant positive effect of urban place on fertility for low- to higher-educated women in Asia and Africa, where most countries are in the intermediate fertility transition stage and the small positive to significantly stronger positive effect of urban place on the fertility of low- to high-educated women in Latin America, where most countries are in the late stages of the fertility transition, suggest some continuity of the effect of place of residence. Our findings suggest that while the fertility of higher-educated women is no longer affected by where they live when countries are in the middle stages of the fertility transition, it is affected once they reach the late stages. For future use in population projection, the empirical evidence from this study can also be used to define the differences between rural and urban fertility for different educational levels from the early to middle to the late transition phase of fertility.

While the above-described literature on the causes of fertility decline as a consequence of female education is quite elaborate, less is known regarding the causes of the additional effect of living in an urban area. In addition to some plausible economic reasons, such as a higher cost of housing in urban areas and higher female labor force participation (which again is related closely to education), there are other plausible mechanisms associated with social learning and diffusion processes, as covered by the extensive literature on diffusion processes in the fertility transition described above.

In principle, such diffusion processes can also be quantitatively studied using DHS data which contain data on small area sample clusters and ideational factors such as ideal family size. One could, for instance, study how the ideal family size of low-educated women in a specific cluster depends on the presence of a group of more-educated women in the same cluster that already has lower family size ideas. This is also in line with some mechanisms that were recently suggested by Dasgupta & Dasgupta (2017) for accelerating the fertility transition through social interactions. While this lends itself to further in-depth studies on trying to quantify these dissemination processes, it goes beyond the scope of this paper, which has set itself a more modest goal in terms of preparing the groups for improved multi-dimensional projects in the context of the SSP Scenarios.

References

Anderson, A. (2010). *Combating Climate Change Through Quality Education*. Brookings Global Economy and Development.

Anderson, A. (2012). Climate Change Education for Mitigation and Adaptation. *Journal of Education for Sustainable Development*, *6*(2), 191–206. https://doi.org/10.1177/0973408212475199

Bongaarts, J. (1987). The proximate determinants of fertility. *Technology in Society*, *9*(3), 243–260. https://doi.org/10.1016/0160-791X(87)90003-0

Browne, E. (2017). *Evidence on education as a driver for migration*. 23.

Chapagain, D. (2018). Present situation of urbanization in Nepal. *International Journal of Humanities, Social Sciences and Education*, *5*(12). https://doi.org/10.20431/2349-0381.0512017

Cleland, J., & Jejeebhoy, S. (1996). Maternal schooling and fertility: evidence from censuses and surveys. *Girls' schooling, women's autonomy and fertility change in South Asia. New Dehli: Sage Publications*, 72-106.

Coale, A. J. (1973). The demographic transition reconsidered. International Union for the Scientific Study of Population. In *Proceedings of the International Population Conference*. Lieja: Éditions Ordina.

Dasgupta, A., & Dasgupta, P. (2017). Socially embedded preferences, environmental externalities, and reproductive rights. *Population and Development Review*, *43*(3), 405–441.

Dunne, A. (2022). *Urban-rural connections could boost resilience in the face of change*. https://ec.europa.eu/research-and-innovation/en/horizon-magazine/urban-rural-connections-could-boost-resilience-face-change

Elkasabi, M. (2021). *DHS.rates: Calculates demographic indicators* (0.9.0) [Computer software]. https://CRAN.R-project.org/package=DHS.rates

Filmer, D., Langthaler, M., Stehrer, R., & Vogel, T. (2018). Learning to realize education's promise. *World Development Report. The World Bank*. https://www.academia.edu/37065276/Learning_to_Realize_Educations_Promise

Garenne, M., & Joseph, V. (2002). The timing of the fertility transition in Sub-Saharan Africa. *World Development*, *30*, 1835–1843. https://doi.org/10.1016/S0305-750X(02)00069-4

Goujon, A. V. (2008). Demographic transition and education in developing countries. *Sustainable Human Development in the Twenty-First Century-Volume II*, 125.

Hughes, A. (2018). Barriers to entering higher education: rural students' perspective. *JITLL*, *1*, 22-7.

Jiang, L., & O'Neill, B. C. (2017). Global urbanization projections for the Shared Socioeconomic Pathways. *Global Environmental Change*, *42*, 193–199. https://doi.org/10.1016/j.gloenvcha.2015.03.008

Jiang, L., & O'Neill, B. C. (2018). Determinants of urban growth during demographic and mobility transitions: Evidence from India, Mexico, and the US. *Population and Development Review*, *44*(2), 363–389. https://doi.org/10.1111/padr.12150

Kc, S., & Lutz, W. (2017). The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100. *Global Environmental Change*, *42*, 181–192. https://doi.org/10.1016/j.gloenvcha.2014.06.004

Kc, S., Wurzer, M., Speringer, M., & Lutz, W. (2018). Future population and human capital in heterogeneous India. *Proceedings of the National Academy of Sciences*, *115*(33), 8328–8333. https://doi.org/10.1073/pnas.1722359115

Kebede, E., Goujon, A., & Lutz, W. (2019). Stalls in Africa's fertility decline partly result from disruptions in female education. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(8), 2891–2896. https://doi.org/10.1073/pnas.1717288116

Kirk, D. (1996). Demographic Transition Theory. *Population Studies*, *50*(3), 361–387. https://www.jstor.org/stable/2174639

Knodel, J., & van de Walle, E. (1979). Lessons from the Past: Policy Implications of Historical Fertility Studies. *Population and Development Review*, *5*(2), 217–245. https://doi.org/10.2307/1971824

Lerch, M. (2017). *Urban and rural fertility transitions in the developing world: A cohort perspective* (WP-2017-011; 0 ed., p. WP-2017-011). Max Planck Institute for Demographic Research. https://doi.org/10.4054/MPIDR-WP-2017-011

Lerch, M. (2019). Regional variations in the rural-urban fertility gradient in the global South. *PLOS ONE*, *14*(7), e0219624. https://doi.org/10.1371/journal.pone.0219624

Lutz, W. (2021). *Advanced Introduction to Demography*. Edward Elgar Publishing.

Lutz, W. (2022). Cognition-driven demographic transition. *N-IUSSP*. https://www.niussp.org/fertility-and-reproduction/cognition-driven-demographic-transition/

Lutz, W., Butz, W. P., & KC, S. (Eds.). (2014). *World Population and Human Capital in the Twenty-First Century*. Oxford University Press.

Lutz, W., Goujon, A., KC, S., Stonawski, M., & Stilianakis, N. (2018). *Demographic and Human Capital Scenarios for the 21st Century: 2018 assessment for 201 countries*. https://doi.org/10.2760/835878

Lutz, W., & Kc, S. (2011). Global human capital: Integrating education and population. *Science*, *333*(6042), 587–592. https://doi.org/10.1126/science.1206964

Lutz, W., & Skirbekk, V. (2014). How education drives demography and knowledge informs projections. In W. Lutz, W. P. Butz, & S. KC (Eds.), *World Population and Human Capital in the Twenty-First Century* (p. 0). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198703167.003.0002

Morselli, D. (2017). *Keep calm and learn Multi-level Logistic modeling: A simplified three-step procedure using Stata, R, Mplus, and SPSS* (No. 1). *30*(1), Art. 1. https://doi.org/10.5334/irsp.90

National Research Council. (2001). *Diffusion Processes and Fertility Transition: Selected Perspectives* (J. B. Casterline, Ed.). The National Academies Press. https://doi.org/10.17226/10228

O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., Rothman, D. S., van Ruijven, B. J., van Vuuren, D. P., Birkmann, J., Kok, K., Levy, M., & Solecki, W. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. *Global Environmental Change*, *42*, 169–180. https://doi.org/10.1016/j.gloenvcha.2015.01.004

Pezzulo, C., Nilsen, K., Carioli, A., Tejedor-Garavito, N., Hanspal, S. E., Hilber, T., James, W. H. M., Ruktanonchai, C. W., Alegana, V., Sorichetta, A., Wigley, A. S., Hornby, G. M., Matthews, Z., & Tatem, A. J. (2021). Geographical distribution of fertility rates in 70 low-income, lower-middle-income, and upper-middle-income countries, 2010–16: A subnational analysis of cross-sectional surveys. *The Lancet Global Health*, *9*(6), e802–e812. https://doi.org/10.1016/S2214-109X(21)00082-6

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (Vol. 1). sage.http://catdir.loc.gov/catdir/enhancements/fy0658/2001057880-t.html

Ritchie, H., & Roser, M. (2018). Urbanization. *Our World in Data*. https://ourworldindata.org/urbanization

Rogers, E. M. (1995). *Diffusion of innovations*. Free Press.

Rogers, E. M. (2003). *Diffusion of Innovations, 5th Edition* (5th edition). Free Press.

Sánchez, A., & Singh, A. (2018). Accessing higher education in developing countries: Panel data analysis from India, Peru, and Vietnam. *World Development*, *109*, 261–278. https://doi.org/10.1016/j.worlddev.2018.04.015

Shapiro, D., & Tambashe, O. (1999). *Fertility transition in urban and rural areas of Sub-Saharan Africa*. Population Research Institute, Pennsylvania State University.

Skirbekk, V. (2008). Fertility trends by social status. *Demographic Research*, *18*, 145–180. https://doi.org/10.4054/DemRes.2008.18.5

Zeleňáková, M., Purcz, P., Hlavatá, H., & Blišťan, P. (2015). Climate Change in Urban Versus Rural Areas. *Procedia Engineering*, *119*, 1171–1180. https://doi.org/10.1016/j.proeng.2015.08.968

Appendix

Appendix A: TFR by education and rural/urban place of residence

Country	Year	Rural			Urban			National		
		lowedu	highedu	total	lowedu	highedu	total	lowedu	highedu	total
Armenia	2000	-	2.123	2.121	-	1.453	1.451	-	1.709	1.708
Armenia	2010	1.813	1.859	1.842	1.839	1.596	1.601	1.826	1.703	1.701
Armenia	2015	2.56	1.788	1.841	3.123	1.626	1.656	2.709	1.705	1.746
Bangladesh	1993	3.543	3.268	3.497	3.244	2.551	2.989	3.518	2.971	3.438
Bangladesh	1996	3.54	2.489	3.383	2.456	2.395	2.427	3.447	2.479	3.268
Bangladesh	1999	3.609	2.899	3.468	2.984	2.328	2.678	3.514	2.715	3.308
Bangladesh	2004	3.275	2.89	3.136	2.775	2.471	2.663	3.176	2.724	3.026
Bangladesh	2007	2.807	2.597	2.736	2.728	2.555	2.614	2.794	2.605	2.71
Bangladesh	2011	2.53	2.313	2.415	2.029	2.054	2.048	2.423	2.233	2.32
Bangladesh	2014	2.404	2.296	2.346	1.939	2.272	2.113	2.293	2.312	2.282
Bangladesh	2017	2.396	2.301	2.305	2.067	2.176	2.13	2.301	2.265	2.251
Benin	1996	6.737	-	6.668	5.382	2.707	4.881	6.258	2.806	5.956
Benin	2001	6.529	4.258	6.412	4.741	3.363	4.391	5.918	3.579	5.608
Benin	2006	6.497	4.407	6.323	5.494	3.479	4.913	6.147	3.671	5.739
Benin	2011	5.661	4.588	5.422	4.826	3.626	4.311	5.337	3.806	4.902
Benin	2017	6.341	4.591	6.062	5.775	4.016	5.176	6.135	4.219	5.685
Bolivia	1994	6.721	4.306	6.288	5.538	2.996	3.827	6.184	3.167	4.766
Bolivia	1998	6.856	4.528	6.409	4.982	2.785	3.323	5.96	2.944	4.228
Bolivia	2003	5.902	3.441	5.46	4.294	2.398	3.116	5.068	2.496	3.838
Bolivia	2008	5.498	3.48	4.936	4.12	2.429	2.836	4.869	2.593	3.537
Burkina Faso	1993	6.999	-	6.97	5.188	2.7	4.602	6.719	3.052	6.515
Burkina Faso	1998	6.911	-	6.895	4.397	2.922	3.948	6.616	2.997	6.431
Burkina Faso	2010	6.839	4.252	6.738	4.506	2.886	3.92	6.384	3.125	5.991
Cameroon	1991	6.49	5.527	6.288	5.923	4.21	5.169	6.296	4.543	5.817
Cameroon	1998	5.648	4.45	5.382	4.848	2.905	3.798	5.463	3.559	4.814
Cameroon	2004	6.371	4.787	6.078	5.102	3.215	4.044	5.873	3.55	4.969
Cameroon	2011	6.79	5.122	6.395	5.128	3.429	3.977	6.207	3.791	5.088
Cameroon	2018	6.333	5.21	5.995	4.932	3.387	3.764	5.847	3.806	4.756
Chad	1996	6.51	-	6.52	6.101	4.349	5.864	6.423	4.836	6.37
Chad	2004	6.532	-	6.498	6.235	4.034	5.751	6.48	4.168	6.344
Chad	2014	6.8	6.693	6.775	6.19	3.942	5.394	6.688	4.828	6.447
Colombia	1995	4.635	3.413	4.305	3.274	2.329	2.518	3.908	2.452	2.971
Colombia	2000	4.255	2.919	3.769	3.112	2.101	2.281	3.636	2.185	2.607
Colombia	2010	3.404	2.49	2.782	3.19	1.874	1.965	3.276	1.966	2.135
Colombia	2015	3.35	2.341	2.601	2.821	1.782	1.804	-	-	-
Cote d'Ivoire	1994	6.096	4.693	5.994	4.815	2.872	4.374	5.611	3.354	5.305
Cote d'Ivoire	1998	6.227	2.073	5.991	4.606	2.417	4	5.671	2.3	5.179
Cote d'Ivoire	2011	6.436	3.929	6.265	4.335	2.409	3.709	5.539	2.643	4.958
Egypt	1992	4.458	4.412	4.489	3.458	3.227	3.363	4.054	3.513	3.932
Egypt	1995	3.96	3.686	3.902	3.313	3.282	3.309	3.733	3.392	3.626
Egypt	2000	3.553	3.71	3.619	3.355	3.435	3.417	3.489	3.535	3.526

Country	Year	Rural			Urban			National		
		lowedu	highedu	total	lowedu	highedu	total	lowedu	highedu	total
Egypt	2003	3.341	3.486	3.364	2.836	3.046	2.977	3.192	3.163	3.183
Egypt	2005	3.113	3.251	3.16	3.08	3.083	3.097	3.105	3.134	3.129
Egypt	2008	2.784	3.209	2.974	3.089	3.12	3.11	2.852	3.139	3.022
Egypt	2014	3.271	3.611	3.51	3.214	3.374	3.347	3.261	3.532	3.466
Ethiopia	2000	6.058	4.609	6.046	3.307	2.694	2.999	5.741	3.168	5.521
Ethiopia	2005	6.106	3.641	6.024	3.089	1.695	2.375	5.829	1.982	5.409
Ethiopia	2011	5.587	2.46	5.463	3.162	1.582	2.634	5.173	1.626	4.803
Ethiopia	2016	5.385	2.534	5.197	2.792	1.853	2.285	5.043	2.071	4.562
Ethiopia	2019	4.651	3.003	4.486	3.337	3.687	3.168	4.311	3.685	4.06
Ghana	1993	6.097	3.373	5.996	3.963	2.693	3.697	5.424	2.847	5.156
Ghana	1998	5.874	4.44	5.263	3.905	2.546	2.958	5.411	3.537	4.439
Ghana	2003	6.408	4.343	5.646	4.304	2.545	3.12	5.739	3.207	4.448
Ghana	2008	5.799	3.845	4.907	4.883	2.486	3.113	5.527	2.996	4.027
Ghana	2014	6.042	4.159	5.089	4.671	3.101	3.44	5.539	3.473	4.194
Guatemala	1995	6.503	2.56	6.149	4.785	2.514	3.803	5.925	2.515	5.134
Guatemala	1998	6.307	2.742	5.84	4.749	3.03	4.06	5.724	2.92	5.038
Guatemala	2014	4.053	2.522	3.69	3.155	2.074	2.457	3.771	2.232	3.128
Guinea	1999	6.108	4.218	6.065	4.785	3.347	4.417	5.753	3.481	5.528
Guinea	2012	5.974	3.647	5.842	4.56	2.783	3.8	5.599	2.989	5.1
Guinea	2018	5.485	5.024	5.451	4.264	3.214	3.842	5.144	3.538	4.824
Haiti	1994	6.154	3.585	5.851	3.997	2.258	3.293	5.427	2.463	4.779
Haiti	2005	5.613	3.061	5.001	3.477	2.146	2.675	4.908	2.415	3.917
Haiti	2012	5.05	3.431	4.418	3.676	2.158	2.601	4.586	2.577	3.532
Haiti	2016	4.788	2.694	3.841	3.036	1.881	2.122	4.263	2.189	3.023
India	1992	4.298	3.496	3.7	3.259	4.008	3.29	4.235	3.378	3.40
India	1998	2.994	2.58	2.924	2.452	2.917	2.665	2.971	2.519	2.846
India	2005	3.401	2.309	2.977	2.818	1.840	2.065	3.825	2.072	2.679
India	2015	2.976	2.075	2.408	2.403	1.641	1.751	2.856	1.903	2.2
Indonesia	1991	3.93	4.289	3.978	4.095	3.913	4.044	3.951	4.054	3.989
Indonesia	1994	3.836	4.306	3.932	3.566	4.012	3.809	3.773	4.113	3.888
Indonesia	1997	3.714	3.922	3.766	3.706	4.048	3.935	3.709	3.943	3.807
Indonesia	2002	3.365	3.705	3.477	3.614	3.974	3.844	3.422	3.84	3.627
Indonesia	2007	3.43	4.007	3.652	3.252	3.701	3.583	3.384	3.847	3.64
Indonesia	2012	2.946	2.835	2.772	2.854	2.423	2.443	2.913	2.59	2.596
Indonesia	2017	2.964	2.595	2.561	2.661	2.314	2.301	2.863	2.434	2.423
Jordan	1990	6.633	6.461	6.591	5.494	4.977	5.212	5.9	5.182	5.573
Jordan	1997	5.353	4.736	4.992	4.239	4.167	4.23	4.557	4.231	4.35
Jordan	2002	4.441	4.114	4.121	3.206	3.579	3.553	3.683	3.657	3.667
Jordan	2007	3.983	4.101	4.03	3.589	3.509	3.512	3.714	3.586	3.591
Jordan	2009	4.855	3.97	4.087	3.635	3.813	3.802	4.025	3.835	3.849
Jordan	2012	4.046	3.967	3.992	3.388	3.397	3.405	3.574	3.489	3.506
Jordan	2017	2.935	3.323	3.27	2.789	2.655	2.669	2.788	2.72	2.729
Kenya	1993	6.119	4.274	5.804	3.447	3.455	3.439	5.794	4.029	5.399
Kenya	1998	5.501	4.17	5.165	3.647	2.536	3.118	5.214	3.531	4.699
Kenya	2008	5.729	3.709	5.177	3.609	2.402	2.92	5.365	3.102	4.558
Kenya	2014	5.148	3.452	4.545	3.738	2.639	3.074	4.699	2.951	3.905
Lesotho	2004	4.415	3.526	4.1	2.096	1.803	1.921	4.012	2.86	3.538

Country	Year	Rural			Urban			National		
		lowedu	highedu	total	lowedu	highedu	total	lowedu	highedu	total
Lesotho	2009	4.742	2.959	3.978	2.294	2.043	2.097	4.189	2.516	3.302
Lesotho	2014	4.426	3.335	3.855	2.228	2.3	2.255	3.935	2.868	3.263
Malawi	1992	6.929	4.627	6.878	5.852	4.386	5.525	6.833	4.368	6.73
Malawi	2000	6.84	3.4	6.665	5.399	2.796	4.506	6.689	3.048	6.348
Malawi	2010	6.359	4.075	6.079	4.861	2.998	4.04	6.168	3.608	5.711
Malawi	2015	5.054	3.51	4.746	3.476	2.819	3.025	4.895	3.196	4.433
Mali	1995	7.322	-	7.301	5.82	3.689	5.405	6.92	4.078	6.71
Mali	2001	7.319	5.94	7.304	6.097	3.708	5.497	7.036	4.147	6.779
Mali	2006	7.241	4.598	7.158	5.943	3.724	5.428	6.872	3.837	6.576
Mali	2012	6.628	4.314	6.455	5.648	3.887	5.02	6.459	3.993	6.099
Mali	2018	6.986	4.787	6.775	5.423	4.215	4.874	6.7	4.521	6.281
Mozambique	1997	5.319	-	5.332	4.956	2.756	4.612	5.252	3.482	5.171
Mozambique	2003	6.171	-	6.145	4.801	2.824	4.406	5.753	2.922	5.532
Mozambique	2011	6.741	4.25	6.627	5.347	3.189	4.528	6.377	3.435	5.921
Nepal	1996	4.836	3.697	4.787	3.727	2.522	3.293	4.754	3.159	4.641
Nepal	2001	4.431	2.775	4.288	2.585	2.527	2.579	4.299	2.647	4.108
Nepal	2006	3.696	2.393	3.331	2.905	1.654	2.136	3.605	2.152	3.134
Nepal	2011	3.42	2.028	2.782	2.416	1.332	1.578	3.327	1.869	2.604
Nepal	2016	3.39	2.535	2.934	2.754	1.724	2.001	3.066	1.945	2.349
Niger	1992	7.132	-	7.125	6.755	3.872	6.407	7.073	3.924	6.993
Niger	1998	7.613	-	7.61	6.116	4.181	5.635	7.359	4.834	7.204
Niger	2006	7.269	-	7.261	6.625	4.397	6.06	7.169	4.793	7.018
Niger	2012	8.155	6.46	8.109	6.217	4.227	5.591	7.878	4.866	7.632
Nigeria	1990	6.531	5.003	6.326	5.828	4.085	5.033	6.415	4.436	6.011
Nigeria	2003	6.68	4.665	6.075	6.26	3.916	4.861	6.574	4.241	5.655
Nigeria	2008	7.166	4.626	6.282	6.488	3.918	4.709	7.019	4.232	5.724
Nigeria	2013	6.838	4.562	6.185	6.19	4.012	4.658	6.684	4.215	5.547
Nigeria	2018	6.625	4.647	5.944	5.994	3.967	4.498	6.459	4.214	5.288
Pakistan	1990	4.922	5.57	4.959	5.037	4.372	4.874	4.926	4.573	4.914
Pakistan	2006	4.4	3.655	4.336	3.881	3.196	3.623	4.257	3.291	4.081
Pakistan	2012	4.152	3.451	4.07	3.506	3.246	3.381	4.002	3.333	3.831
Pakistan	2017	3.867	3.577	3.831	3.232	3.095	3.161	3.692	3.227	3.557
Peru	1991	6.83	4.36	6.187	4.08	2.429	2.758	5.433	2.599	3.543
Peru	1996	6.252	3.847	5.579	4.177	2.505	2.798	5.305	2.646	3.536
Peru	2000	4.954	3.034	4.337	3.015	2.073	2.217	4.241	2.21	2.847
Peru	2010	4.079	3.109	3.51	3.153	2.194	2.189	3.73	2.224	2.53
Peru	2011	4.103	3.014	3.511	3.19	2.092	2.288	3.756	2.319	2.589
Peru	2012	4.023	2.952	3.458	3.348	2.207	2.26	3.589	2.332	2.558
Philippines	1993	6.028	3.869	4.824	4.633	3.189	3.528	5.468	3.428	4.089
Philippines	1998	5.895	3.984	4.674	3.463	2.933	3.012	4.996	3.303	3.73
Philippines	2008	4.534	3.551	3.828	4.361	2.646	2.829	4.472	2.989	3.262
Philippines	2013	4.882	3.157	3.525	3.837	2.51	2.627	4.535	2.782	3.04
Philippines	2017	4.246	2.712	2.923	3.812	2.296	2.402	4.102	2.494	2.663
Rwanda	1992	6.454	4.589	6.334	4.939	3.591	4.515	6.391	4.245	6.231
Rwanda	2000	5.983	5.383	5.936	5.52	4.536	5.178	5.946	4.891	5.835
Rwanda	2005	6.399	4.8	6.306	5.399	3.723	4.908	6.271	4.339	6.076
Rwanda	2007	5.807	3.843	5.663	5.088	3.808	4.71	5.72	3.831	5.514

Country	Year	Rural			Urban			National		
		lowedu	highedu	total	lowedu	highedu	total	lowedu	highedu	total
Rwanda	2010	4.976	2.993	4.759	3.71	3.082	3.44	4.839	3.027	4.563
Rwanda	2014	4.582	3.323	4.308	4.137	2.85	3.565	4.52	3.048	4.165
Rwanda	2019	4.5	4.071	4.317	3.531	3.342	3.399	4.374	3.729	4.126
Senegal	1992	6.762	4.952	6.737	5.5	3.653	5.063	6.296	3.747	6.029
Senegal	1997	6.773	5.91	6.744	4.788	2.746	4.295	6.023	3.071	5.669
Senegal	2005	6.45	4.251	6.371	4.573	2.762	4.091	5.658	2.947	5.257
Senegal	2010	6.201	4.296	6.039	4.474	2.686	3.911	5.464	2.904	4.984
Senegal	2015	6.42	4.759	6.118	4.172	2.613	3.502	5.514	3.053	4.857
Senegal	2017	6.209	4.012	5.888	3.861	2.882	3.369	5.248	3.183	4.615
Senegal	2018	5.86	4.062	5.461	3.918	2.459	3.207	5.101	2.816	4.357
Senegal	2020	5.978	4.164	5.637	4.416	3.308	3.789	5.366	3.579	4.726
Sierra Leone	2008	5.959	4.39	5.845	4.693	2.792	3.794	5.655	3.129	5.123
Sierra Leone	2013	5.934	4.286	5.697	4.4	2.461	3.454	5.572	2.956	4.911
Sierra Leone	2019	5.389	4.408	5.14	4.038	2.554	3.128	4.994	3.041	4.218
Tanzania	1991	6.637	4.017	6.584	5.272	4.246	5.137	6.337	4.218	6.244
Tanzania	1996	6.413	3.587	6.344	4.261	2.999	4.098	5.957	3.139	5.816
Tanzania	1999	6.52	4.908	6.483	3.174	3.018	3.16	5.663	3.541	5.554
Tanzania	2004	6.541	4.621	6.461	3.857	2.831	3.61	5.893	3.304	5.659
Tanzania	2010	6.434	2.895	6.104	4.115	3.006	3.735	5.889	2.955	5.434
Tanzania	2015	6.351	4.14	5.995	4.189	3.35	3.802	5.718	3.643	5.198
Turkey	1993	4.329	3.041	4.268	3.643	2.939	3.47	3.919	2.943	3.746
Turkey	1998	3.249	2.007	3.085	2.875	1.766	2.386	3.011	1.805	2.609
Turkey	2003	4.406	3.017	4.198	3.644	2.869	3.361	3.92	2.883	3.607
Turkey	2008	4.442	3.31	4.066	3.711	3.026	3.342	3.932	3.082	3.519
Turkey	2013	3.371	1.957	2.733	3.014	1.958	2.156	3.082	1.987	2.258
Uganda	1995	7.278	6.217	7.166	5.68	3.812	4.972	7.122	5.15	6.858
Uganda	2000	7.739	4.423	7.364	4.761	3.179	4.012	7.451	3.867	6.852
Uganda	2006	7.474	5.096	7.134	5.288	3.567	4.397	7.249	4.415	6.673
Uganda	2016	6.299	4.756	5.91	4.554	3.659	3.994	5.996	4.215	5.38
Zambia	1992	7.32	5.324	7.135	6.346	4.813	5.797	6.923	4.926	6.463
Zambia	1996	7.027	5.854	6.861	6.028	4.071	5.082	6.7	4.526	6.08
Zambia	2001	7.263	5.188	6.92	5.252	3.245	4.282	6.7	3.863	5.881
Zambia	2007	7.849	5.394	7.475	5.67	3.283	4.272	7.281	3.874	6.169
Zambia	2013	7.09	5.032	6.558	4.828	3.196	3.733	6.427	3.764	5.263
Zambia	2018	6.291	4.629	5.832	4.326	3.058	3.41	5.731	3.57	4.685
Zimbabwe	1994	5.192	3.729	4.85	3.271	3.002	3.094	4.785	3.323	4.287
Zimbabwe	1999	4.981	3.757	4.567	3.148	2.915	2.961	4.599	3.262	3.964
Zimbabwe	2005	5.036	3.992	4.584	2.471	2.591	2.582	4.637	3.231	3.798
Zimbabwe	2010	5.177	4.63	4.757	3.557	3.023	3.083	4.88	3.834	4.102
Zimbabwe	2015	5.375	4.33	4.701	3.143	2.982	2.994	5.068	3.664	4.024

Appendix B: Countries and survey years used in the multi-level analysis

Country	Demographic and health survey years					
Afghanistan	2015					
Angola	2015					
Armenia	2000	2010	2016			
Azerbaijan	2006					
Bangladesh	1997	2004	2007	2014	2017	
Benin	1996	2001	2006	2012	2018	
Bolivia	1989	1998	2003	2008		
Brazil	1986	1991	1996			
Burkina Faso	1993	1999	2010			
Burundi	1987	2010	2016			
Cambodia	2010	2014				
Cameroon	1991	1998	2011	2018		
Chad	1997	2004	2015			
Colombia	1986	1995	2005	2010	2015	
Comoros	1996	2012				
Congo	2005	2011				
Cote d'Ivoire	1994	2012				
Dominican Republic	1986	1991	1996	2002	2007	2013
Egypt	1988	1992	1995	2003	2008	2014
Ethiopia	1992	2003	2008			
Gabon	2000	2012				
Gambia	2013	2020				
Ghana	1988	1993	1998	2003	2008	2014
Guatemala	1987	1995	2015			
Guinea	1999	2012	2018			
Guyana	2009					
Haiti	1994	2006	2012	2017		
Honduras	2006	2012				
India	1993	1999	2015			
Indonesia	1987	1991	1997	2002	2007	2012	2017
Jordan	1990	1997	2002	2007	2012	2017
Kenya	1989	1993	1998	2009	2014	
Lesotho	2009	2014				
Liberia	1986	2007	2013	2019		
Madagascar	1992	1997	2004	2009		
Malawi	1992	2000	2010	2015		
Maldives	2009	2017				
Mali	1987	1996	2001	2006	2012	2018
Morocco	1987	1992				
Mozambique	1997	2003	2011			
Myanmar	2016					

Country	Demographic and health survey years					
Namibia	1992	2000	2013			
Nepal	1996	2001	2011	2016		
Nicaragua	1998	2001				
Niger	1992	1998	2006	2012		
Nigeria	1990	2003	2008	2013	2018	
Pakistan	1991	2012	2018			
Peru	1986	1991	1996	2000	2007	2010
Philippines	1993	1998	2003	2008	2013	2017
Rwanda	1992	2005	2008	2011	2020	
Sao Tome and Principe	2008					
Senegal	1986	1997	2005	2012	2018	
Sierra Leone	2008	2013	2019			
South Africa	1998	2016				
Tajikistan	2012	2017				
Tanzania	1991	1996	2004	2010	2015	
Timor-Leste	2009	2016				
Togo	1988	1998	2014			
Turkey	1993	1998	2004	2008	2013	
Uganda	1988	1995	2001	2006	2011	2016
Yemen	1991					
Zambia	1992	1996	2002	2007	2013	2018
Zimbabwe	1988	1994	1999	2005	2010	2015