DISSERTATION/DOCTORAL THESIS

Titel der Dissertation /Title of the Doctoral Thesis

Understanding Differentials by Level of Education in Fertility Intentions and Behaviors in Lower- and Middle-Income Countries

verfasst von / submitted by

Saroja Adhikari

angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Doktorin der Philosophie (Dr. phil.)

Wien, 2023 / Vienna, 2023

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	UA 796 310 120
Dissertationsgebiet lt. Studienblatt / field of study as it appears on the student record sheet:	Demografie
Betreut von / Supervisor:	Univ.-Prof. Mag. Dr. Wolfgang Lutz Prof. Dr. Samir K.C.

Abstract

This dissertation addresses the importance of understanding future population dynamics for effective resource allocation and sustainable planning. While numerous organizations project future populations, the Wittgenstein Centre for Demography and Global Human Capital (IIASA, OeAW, Univ. Vienna) stands out by incorporating heterogeneity based on educational levels, alongside age and sex, and incorporating substantive assumptions in addition to statistical models. Recognizing that the future population of lower and middle-income countries (LMIC) depends heavily on fertility behavior, this study looks into reproductive intentions and behaviors across diverse contexts and regions in LMIC, focusing on the educational levels of women.

The dissertation investigates the diffusion of fertility preferences and behaviors, the impact of urbanization on fertility behavior, and gender preferences among women of various educational backgrounds in LMICs using comprehensive demographic and health surveys in a large number of countries. In addition, the study also investigates the way to incorporate urbanization and diffusion while projecting fertility in a multidimensional population projection model.

Three key findings emerge from the studies are: 1) Urbanization, in addition to individual education, plays a critical role in reducing fertility in LMIC; 2) Fertility intentions and behaviors in Africa are shaped not only by an individual's education but also by the average educational levels of neighbors and peers in close proximity, due to a diffusion effect; 3) In the case of Nepal, the education levels of neighbors and peers in close proximity strongly influence son preferences. These findings are crucial for demographic projections, emphasizing the need to consider diverse sources of heterogeneity affecting fertility in LMIC. The study points atthe

importance of including urbanization and diffusion effects in future fertility projections and indicates a way of to do this, providing valuable insights for more accurate projections and informed policy decisions.

Kurzfassung

Diese Dissertation beschäftigt sich mit der Notwerndigkeit, die zukünftige Bevölkerungsdynamik zu verstehen, um Ressources besser zu verteilen und nachhaltig zu planen. Unter den Organisationen, die Bevölkerungsprognosen erstellen differenziert nur das Wittgenstein Centre (IIASA, OeW, Univ. Wien) zusätzlich zu Alter und Geschlecht auch nach der höchsten abgschlossenen Schulbildung. Dabei werden auch inhaltliche Annahmen zur zukünftigen Entwicklung mit statistischen Modellen kombiniert. Da die zukünftige Bevölkerungsentwicklung in Ländern mit niedrigem und mittlerem Einkommen (LMIC) stark von der zukünftigen Fertilitätsentwicklung beeinflußt wird, beschäftigt sich diese Arbeit mit den reproduktiven Intentionen und Verhalten in diesen Ländern unter besonderer Berücksichtigung von Bildung.

Die Arbeit untersucht die Diffusion von Fertilitätspräferenzen und des reproductiven Verhaltens, sowie den Einfluss von Urbanisierung und Geschlechtspräferenzen für die Kinder auf der Basis umfassender internationaler Umfragedaten (Demographic and Health Surveys, DHS). Es geht dabei auch um die Operationalisierung dieser Faktoren für die Erstellung multi-dimensionaler demografischer Prognosen.

Drei Hauptresultate ergeben sich aus dieser Arbeit: 1) Urbanisierung ist zusätzlich zur individuellen Bildung ein wichtiger Faktor in der Reduktion der Fertilität in LMIC Ländern; 2) Reproduktive Intentionen und Verhalten in Afrika hängen nicht nur von der eigenen Bildung der Frauen, sondern auch vom Bildungsniveau im Lebensumfeld ab, was auf Diffusionseffekte hindeutet; 3) Im Falle Nepals wirkt sich der Einfluss der Umgebung auch deutlich auf die Präferenz für Söhne aus. Dies sind für demografische Prognosen wichtige Erkenntnisse, die auf die Notwendigkeit der Berücksichtigung von Heterogeneität der Bevölkerungen über Alter und Geschlecht hinaus verweisen. Die explizite Einbeziehung von Urbanisierung und Diffusionsprozessen zwischen Bildungsgruppen in

Prognosemodelle kann somit zu besseren Prognosen mit höherer Relevanz für Planung on Politik beitragen.

Contents

Abstract iii

1 Introduction 9

1.1 Motivation 9

1.2 Problem Statement and Research Gaps 14

1.3 Research Objectives and Questions 16

1.4 Data and Methods 18

1.5 Thesis Structure 20

2 Thesis Articles 21

2.1 Rural/urban fertility differentials in the Global South: Is female education the key driver of declining birth rates? 21

2.2 Africa's fertility decline is partly driven by diffusion processes among education groups. 59

2.3 Examining the role of female education on son preference among Nepalese women 87

3 Conclusion 116

3.1 Main findings 116

3.2 Acknowledgement 120

1 Introduction

1.1 Motivation

In lower and middle-income countries, where fertility rates remain notably high and developmental progress is relatively slower, the importance of studying current and future fertility is very important. The future population growth worldwide and in these regions heavily depends on the future fertility rates. Therefore, understanding and projecting these rates are crucial for policymakers, resource allocators, public health experts, and governments striving to navigate the delicate balance between population growth and sustainable development. Fertility projection serves as an important tool in shaping targeted interventions and policies that address the specific needs of these societies, influencing healthcare, education, climatic change, and socio-economic initiatives. To better understand future fertility rates, developing better assumptions based on solid scientific reasoning is crucial. The accuracy of predicting these rates relies heavily on the quality of these fertility models and their assumptions, forming the foundation for projection.

Different agencies producing population projections have different ways of projecting future fertility trajectories. The United Nations (UN), a prominent source, projects future populations based on age and sex as dimensions of population heterogeneity (United Nations, 2022). The UN's model relies on historical fertility trends without explicitly considering the impact of changing socio-economic development on the total fertility rate (TFR). Similarly, the US Census Bureau (USCB) mainly extrapolates past trends in TFR for its fertility projection (US Census Bureau, 2020). The Institute for Health Metrics and Evaluation (IHME) projects fertility in various education and health scenarios, but unlike other agencies, it forecasts the completed cohort fertility rate instead of TFR (Vollset et al., 2020). Completed cohort fertility rate may not be as useful for policymakers to address recent changes in fertility rates or implement effective fertility policies regarding recent changes in family planning and socio-economic factors. Despite offering long-term fertility projections, these organizations do not thoroughly substantiate their assumptions and overlook additional dimensions beyond conventional age and sex that contribute to fertility heterogeneity. The multidimensional fertility projection model of the Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, W.U.) incorporates education in addition to age and sex as an additional dimension of heterogeneity(Lutz et al., 2014). The first step in the multidimensional fertility projection model involves projecting the future total fertility rate (TFR). This projection is based on historical time series TFR estimates and expert assumptions about future scenarios. Educational differentials in TFR are introduced after the overall TFR projection. The projected overall TFR trend is subdivided into distinct trajectories based on TFR ratios of five educational levels: no education, incomplete primary, completed primary, lower secondary and upper secondary with post-secondary. Starting with the ratios observed at the baseline period, the model assumes a convergence ratio 1.42 for those up to primary completion. And 1.35 and 1.14 for lower and upper secondary, respectively. For countries where the maximum differential was lower than 1.42 in the base year, the relative ratios were maintained at those lower levels throughout the projection period with a lower limit of 1.05. Even though the multidimensional fertility projection model includes education as an additional dimension beyond age and sex, because of the data limitation, it still lacks an explicit consideration of the effect of changing educational composition on future fertility.

Over the past century, the literature has identified multiple sources of fertility heterogeneity that determine the changes in fertility levels across different times and regions, such as age, sex, education, income, urbanization, labour force participation, etc. Education has long been recognized as crucial in understanding historical demographic changes worldwide. The literature consistently highlights the positive association between female education and lower fertility (Frye & Bachan, 2017; Fuchs, 2012; Kebede et al., 2019; Lutz, 2017; Lutz et al., 2013).

Higher education is associated with lower fertility rates through various pathways. More time spent in school or college lowers the time exposure to pregnancy, which mainly reduces adolescent fertility in lower and middle-income countries (Santelli et al., 2017). Educated women are more likely to participate in the labour force, which limits their time for childbearing and child-rearing. Women with higher educational attainment often prioritize career aspirations over dedicating substantial time and energy to raising children (Bhalotra et al., 2022; Krishnan, 1991). Education is associated with lower family size intentions, reflecting an ideational shift towards smaller family size(Behrman, 2015; Berrington & Pattaro, 2014; Kebede et al., 2022). Educated women have a better awareness and understanding of reproductive health, including access to modern contraception, which makes it easier to turn fertility intentions into reality (Bongaarts, 2010; Lutz, 2017; Saleem & Bobak, 2005). Additionally, urban areas had a higher proportion of educated women, and urbanization is associated with lower fertility rates (Filmer et al., 2018; Lerch, 2019). Considering the diverse impacts of education on fertility, explicitly integrating education as an additional dimension in the fertility projection model can implicitly encompass various socio-economic effects (effects of labour force participation, women empowerment, contraception, and ideational shift on fertility) on fertility.

Urbanization is gaining increased attention as a significant factor in fertility heterogeneity, particularly in lower and middle-income countries. Across the demographic transition period in these regions, consistent differences in fertility rates have been identified between rural and urban areas (Galloway et al., 1998; Lerch, 2017, 2019b; Shapiro & Tambashe, 1999). Some organizations, including the UN, have begun incorporating urbanization as a dimension in future population projections, recognizing its impact on population dynamics (Jiang & O'Neill, 2017; UN, 2018, 2021). However, they lack a systematic analysis regarding the importance of introducing urbanization as a new dimension. Notably, none of these organizations have projected future fertility by considering the explicit effects of urbanization. Urban areas tend to have a higher proportion of educated women, and higher female education is associated with lower fertility rates (Filmer et al., 2018). The observed impact of urbanization on fertility may, therefore, stem from differences in the educational distribution between rural and urban regions. Therefore, it is crucial to systematically investigate whether the educational disparities between these regions can elucidate the impact of urbanization on fertility before introducing urbanization as a new dimension in the multidimensional fertility projection model.

Scholars exploring the impact of urbanization on fertility have pointed towards the diffusion effect contributing to the disparities in fertility between rural and urban areas. Although urbanization is associated with declining fertility, the specific mechanisms influencing this reduction remain unexplored. Lerch (2017) has mentioned that the rural and urban fertility differential across different periods may be attributed to the spatial and structural diffusion of lower fertility intentions and behaviours. As human beings are inherently social creatures, their behaviour is significantly influenced by the actions and attitudes of others within their society. This phenomenon arises from a fundamental need for social interaction and acceptance. Individuals seek conformity or validation for their behaviour from peers, family, and community members (Asch, 1956). The collective behaviour that emerges from these interactions is often regarded as social norms, serving as guidelines for acceptable conduct within a given society (Cialdini & Goldstein, 2004). These norms shape various aspects of human behaviour, including social roles, etiquette, values, and even personal beliefs and decisions. Diffusion processes are likely to play a crucial role in such social learning behaviour through interactions impacting the demographic change, where the ideational norms and behavioural patterns of the more educated avant-garde tend to be successively adapted by less educated groups. This dissertation follows Bongaarts & Watkins (1996), who suggested that apart from socio-economic determinants, fertility declines are accelerated by social interaction in close geographical or social proximity. Through this mechanism, lower fertility ideals and subsequent behaviours then diffuse to less educated women living close to more educated women. By exploring the social learning effect through diffusion, this dissertation seeks to model the social learning effect on fertility to better forecast future fertility rates.

This dissertation broadens its scope by investigating the impact of social learning, not only on the number of children but also on the gender preferences of children. Given that son preference has been influencing the fertility and population structure of many South Asian countries, including Nepal (Abeykoon, 1995; Banister, 1994; Ebenstein & Leung, 2010; Javed et al., 2019; Wongboonsin & Ruffolo, 1995), the dissertation investigates how the changing educational composition of society can affect such preferences. Nepal, located between the world's two most populous countries, India and China, shares similar cultural and traditional values, making it a representative case study for studying son preferences in the context of changing educational composition. Despite the illegality of sex-selective abortion, Nepal has witnessed a substantial increase in the sex ratio at birth (SRB), escalating from 106 male births per female births in 1996 to a significant 119.1 in 2022 (Ministry of Health and Population et al., 2022). This clear male bias in SRB highlights the urgent need for research to address and mitigate son preference in Nepal. The dissertation looks into how a woman's education and the overall education level in society influence her preferences for the gender of her children. It is based on the idea that social norms regarding gender preference tend to follow what the majority prefers, and the minority adopts these preferences to feel a sense of belonging in society. For example, suppose a woman with a lower education or no education live in a community where majority of her peers or neighbours have higher level of education. In that case, that woman might prefer the same gender as those with higher education to establish a sense of belonging in the community and vice versa. This study sheds light on the critical role of female education in influencing son preference and investigates how this preference changes as society's educational composition changes. This research aligns with the evolving SRB in South Asian countries, which directly influences both current and future population structures.

1.2 Problem Statement and Research Gaps

This dissertation addresses a research gap in the existing method of fertility projections, particularly in lower and middle-income countries. As outlined in the introduction, various organizations have focused on age and sex structures in the projection of population components. While some have expanded to include urbanization as an additional dimension, none have explicitly incorporated the impact of urbanization on fertility behaviour. Notably, the mechanism through which urbanization affects fertility remains unknown. The Wittgenstein Centre for Demography and Global Human Capital, recognizing the effect of education on population dynamics, attempted to include education in their multidimensional population projection model. However, due to limited data on education-specific fertility, they resorted to indirect methods, leading to an oversight in capturing the changing educational composition's effect on fertility.

To address these limitations, this dissertation aims to enhance the accuracy of the multidimensional fertility projection model of the Wittgenstein Centre by systematically investigating three key research areas. The first focus is on the importance of incorporating urbanization into a multidimensional fertility projection model. Despite some research indicating the importance of including urbanization in addition to education in multidimensional population projections for a specific country (KC et al., 2018), this effect has not been rigorously investigated in low- and middle-income countries. By seeking to understand the additional impact of urbanization on fertility on top of women's education, the research aims to contribute valuable insights into the complex relationship between education, urbanization and fertility. Secondly, the dissertation looks into the diffusion process as a potential mechanism behind the effect of urbanization on fertility. In urban areas, where the proportion of higher educated women is high, those with lower education might adopt the fertility behaviour of their more educated peers, resulting in lower fertility rates than less educated women in rural areas. Instead of looking at the differences between dichotomized rural and urban regions, this dissertation takes a more granular approach by investigating the diffusion process within smaller geographical areas or communities. In those close-knit areas defined as "stratum" in Demographic and Health Survey (DHS) data, women of varying education levels interact more intensively, enabling them to learn from each other's intentions and behaviours. By including the social learning effect on fertility through diffusion, this dissertation also provides a method to capture the changing educational composition's effect on the projection of TFR.

Finally, the dissertation also investigates this compositional effect of education on the son preference at birth. While extensive research has been conducted on son preference in countries like India and China, Nepal, situated between these two large nations and sharing similar cultural elements, has received comparatively less attention. Exploring son preference in Nepal holds crucial importance due to its direct influence on the sex ratio at birth (SRB). Over the past 25 years, Nepal has witnessed a substantial increase in the sex ratio at birth (SRB), increasing from 106 to 119.1. However, the multidimensional population projection model has been using a consistently normal SRB of 1.05 to 1.07 during the same period and forecasted to 1.06 over the projection period (Wittgenstein Centre for Demography and Global Human Capital, 2018). This discrepancy prompts a critical examination of the model's assumptions against the observed demographic reality. Moreover, the escalating male-biased SRB is not exclusive to Nepal but is a phenomenon observed across various Asian countries (Almond et al., 2013; Frost et al., 2013), highlights gender-based discrimination against women as well as the rising trend of illegal sex-selective abortions. This dissertation investigates how female education plays a critical role in addressing the pervasive issue of son preference in Nepal. It aims to shed light on the importance of understanding and addressing son preference, particularly in the changing landscape of educational compositions, to gain insights into its potential impact on future fertility behaviours.

1.3 Research Objectives and Questions

The dissertation is structured around three interconnected objectives, each contributing to a thorough understanding of fertility dynamics in lower and middle-income countries. These objectives play a crucial role in refining the Wittgenstein Centre's multidimensional fertility projection model, enhancing its precision in forecasting future fertility rates. First and foremost, the aim is to explore the significance of incorporating urbanization as an additional dimension in the fertility projection model alongside age, sex, and education. This exploration is important for capturing fertility heterogeneity across countries and regions, providing a nuanced understanding of the determinants of fertility variations.

Given the observed disparities in rural and urban fertility and the hint towards diffusion as a mechanism behind the impact of urbanization in fertility, the second objective centres on unravelling the diffusion process in fertility. Specifically, it investigates the diffusion effect in fertility intention and behaviour and seeks to integrate this effect into the fertility projection model. This innovative approach fills the research gap of conventional assumptions about education-specific fertility, offering a more reliable quantitative method that considers the changing educational composition's impact on the TFR based on a country's MYS.

The third objective delves into the investigation of the role of MYS within communities and its influence on son preference in Nepal. This exploration is crucial for understanding the changes in SRB resulting from shifts in educational composition. It also helps the policymaker to make precise decisions to mitigate the pressing need of sex-selective abortions.

Based on these objectives and the significance of each objective, the following research questions are addressed in this dissertation.

I. Does urbanization have an additional effect on fertility in addition to female education? How can this urbanization effect be integrated into the multidimensional fertility projection model?

II. How does the diffusion process, particularly through female education, influence the fertility dynamics of Africa, and how can this diffusion effect be effectively integrated into the multidimensional fertility projection model?

III. How does the changing educational composition impact the son preference in Nepal? What matters more for son preference: individual education or collective community education?

This dissertation aims to evaluate the determinants of fertility heterogeneity and the significance of incorporating these determinants as a dimension of a multidimensional fertility projection model to improve the ability to predict future demographic changes more accurately. Better population projections are required for the development of effective plans and policies that will guide future populations toward sustainable societies. These projections are a critical tool for policymakers, allowing them to anticipate demographic trends, plan resource allocation, address healthcare needs, do urban planning and develop educational and social programs that are in sync with the changing population structure. Different organizations and scholars working in the field of population projection can use the new method proposed by this dissertation to better forecast future fertility rates and population size and structure. By understanding how populations are likely to change by age, gender, education, and place of residence in the coming years, stakeholders and policymakers can make informed decisions.

1.4 Data and Methods

This dissertation relies primarily on comprehensive Demographic and Health Surveys (DHS) data from 1986 to 2022, covering a diverse array of countries across Africa, Asia, Latin America and the Caribbean. The empirical analysis draws from a substantial sample size, encompassing over 3 million women, reflecting the richness and diversity of various regions and contexts. Addressing the first research question entails estimating the Total Fertility Rate (TFR) among rural, urban, and different educational categories within both rural and urban settings and at the national level. This estimation is conducted for 30 countries surveyed at least three times from 1986 to 2022. The subsequent step involves a comparative analysis of the TFR trends to discern patterns in the differences between rural and urban fertility across various education levels over the fertility transition period. The overarching patterns observed in rural and urban fertility, stratified by education level, serve as a valuable guide for projecting the anticipated disparities in TFR between rural and urban areas throughout the transition period.

Furthermore, the analysis employs multilevel regression models to estimate the interaction effect between place of residence (rural/urban) and education across the entire sample from 63 lower and middle-income countries. This statistical approach is instrumental in discerning the additional impact of urbanization, complementing the effect of female education on fertility. The resulting numeric estimates from these interactions provide valuable insights and directly contribute to projecting future fertility by introducing urbanization as a new dimension in the fertility projection model.

The second research question is developed based on the hypothesis that lower fertility behaviour emerges among highly educated women who are ahead of others in recognizing the advantages of having a smaller family. We follow Bongaarts & Watkins (25), who suggested that apart from socio-economic determinants, fertility declines are accelerated by social interaction in close geographical or social proximity. Through this mechanism, lower fertility ideals and subsequent behaviours then diffuse to less educated women living close to more educated women. To address the second research question, an in-depth analysis is conducted using DHS data collected between 1986 and 2022 from 39 African countries. A multilevel logistic regression model is used to estimate the interaction effect of women's individual education and the MYS of women in the community where they reside on fertility intention and behaviour. The fertility intention and behavioural pattern observed among women with different education levels living in a community with varying MYS supports the diffusion process in both fertility intention and behaviour. To enhance our understanding of the diffusion process in fertility, we used recently developed time series data on education-specific fertility (Durowaa-Boateng et al., 2023) and MYS, spanning from 1980 to 2015, sourced from the Wittgenstein Centre Human Capital Data Explorer. This allowed us to estimate the change in TFR per unit change in MYS for each country and education level. Subsequently, we computed the average of these TFR changes per unit change in MYS across all countries for each education level, terming it the "diffusion rate." This diffusion rate is then used to forecast the future TFR for selected African countries. This novel method of fertility projection incorporates the effect of changing educational composition on the future TFR.

The third research question is answered using the Nepal DHS (NDHS) data collected between 1996 and 2022. The research question is built upon the hypothesis that son preference in birth is a prevalent social norm in Nepal. Women feel compelled to have sons because of social pressure. However, when women live in a community where the majority of women have higher levels of education, the prevailing social norms in that community may lean more towards a reduced emphasis on son preference, aligning with the attitudes expected to see in highly educated women. Women may encounter less societal pressure to have a son in such cases. Therefore, an increase in mean years of schooling in a community decreases son preference. Using the multivariate and multilevel regression model, the trend of son preference over the last 25 years estimates the effect of women's individual education and the compositional effect of education in son preference.

1.5 Thesis Structure

This dissertation is structured into three sections. Each section includes a separate publication and has separate research questions, methods and data use. However, all three sections contribute to understanding the role of education on fertility and making the fertility projection model better by incorporating the new techniques into the model.

The first paper entitled "Rural/urban fertility differentials in the Global South: Is female education the key driver of declining birth rates?" (published as IIASA working paper in IIASA PURE on 20 April 2023, submitted to Asian Population Studies Journal on 13 June 2023, currently under peer review) focus on understanding the additional effect of rural and urban place of residence on fertility on top of female education. The research carried out across 63 lower- and middle-income countries sought a systematic analysis emphasizing the significance of integrating urbanization as an additional dimension to comprehensively capture fertility heterogeneity in a multidimensional fertility projection model. The findings indicate an additional impact of urbanization on fertility, although the specific mechanisms driving this urbanization effect remain to be explored. The paper not only offers significance and guidelines for the inclusion of urbanization in the multidimensional population projection model but also suggests further exploration of mechanisms, such as the diffusion of behaviour behind the urbanization effect. This deeper understanding of the mechanism can help to unravel the complexities of the urbanization effect and its potential evolution in influencing fertility trends in the future.

The second paper is “Africa’s fertility decline is partly driven by diffusion processes among education groups” (submitted to *Proceedings of the National Academy of Sciences journal* on 17 November 2023). This paper focuses on capturing the diffusion processes within fertility preferences and behaviours among women with varying education levels in Africa’s fertility dynamics. It presents compelling evidence highlighting the importance of incorporating these diffusion processes into fertility projections, complementing the individual educational effects on fertility. The paper takes an innovative approach by introducing a novel fertility projection method that considers the diffusion effect on fertility, which explicitly includes the effect of changing educational composition on the TFR. Incorporating the diffusion effect into a multidimensional fertility projection model not only accounts for the social learning impact that is an inherent characteristic of human behaviour but also provides a more data-driven approach to accounting for the changing educational effects on fertility.

The third paper is “Examining the Role of Female Education in the Son Preferences among Nepalese women” (published as IIASA working paper in *IIASA PURE* on 24 November 2023, Submitted to *Asian Population Studies Journal* on 18 September 2023, currently under peer review). This study aims to provide policymakers with instructive insight into the potential impact of investing in female education as a strategy to reduce son preference in Nepal. A significantly higher male-biased sex ratio at birth suggests sex-selective abortions, which result from son preference. The research highlights the likelihood of shifts in such preferences and, consequently, the SRB with evolving educational compositions across the country by examining the influence of both individuals and the overall educational level of communities on son preference. The findings are intended to help population projection organizations understand how the SRB in countries like Nepal may evolve in the future, particularly in light of changing educational dynamics.

References (Section 1.1 to 1.5)

Abeykoon, A. T. (1995). Sex preference in South Asia: Sri Lanka an outlier. *Asia-Pacific Population Journal*, *10*(3), 5–16.

Almond, D., Edlund, L., & Milligan, K. (2013). Son Preference and the Persistence of Culture: Evidence from South and East Asian Immigrants to Canada. *Population and Development Review*, *39*(1), 75–95. https://doi.org/10.1111/j.1728-4457.2013.00574.x

Asch, S. E. (1956). Studies of independence and conformity: I. A minority of one against a unanimous majority. *Psychological Monographs: General and Applied*, *70*, 1–70. https://doi.org/10.1037/h0093718

Banister, J. (1994). *Son Preference in Asia—Report of a Symposium*.

Behrman, J. A. (2015). Does Schooling Affect Women's Desired Fertility? Evidence From Malawi, Uganda, and Ethiopia. *Demography*, *52*(3), 787–809. https://doi.org/10.1007/s13524-015-0392-3

Berrington, A., & Pattaro, S. (2014). Educational differences in fertility desires, intentions and behaviour: A life course perspective. *Advances in Life Course Research*, *21*, 10–27. https://doi.org/10.1016/j.alcr.2013.12.003

Bhalotra, S., Clarke, D., & Walther, S. (2022). *Women's Careers and Family Formation*.

Bongaarts, J. (2010). The causes of educational differences in fertility in sub-Saharan Africa. *Poverty, Gender, and Youth*. https://doi.org/10.31899/pgy3.1023

Bongaarts, J., & Watkins, S. C. (1996a). Social Interactions and Contemporary Fertility Transitions. *Population and Development Review*, *22*(4), 639–682. https://doi.org/10.2307/2137804

Bongaarts, J., & Watkins, S. C. (1996b). Social Interactions and Contemporary Fertility Transitions. *Population and Development Review*, *22*(4), 639–682. https://doi.org/10.2307/2137804

Cialdini, R. B., & Goldstein, N. J. (2004). Social influence: Compliance and conformity. *Annual Review of Psychology*, *55*, 591–621.https://doi.org/10.1146/annurev.psych.55.090902.142015

Durowaa-Boateng, A., Yildiz, D., & Goujon, A. (2023). A Bayesian model for the reconstruction of education- and age-specific fertility rates: An application to African and Latin American countries. *Demographic Research*, *49*, 809–848. https://www.demographic-research.org/articles/volume/49/31

Ebenstein, A., & Leung, S. (2010). Son Preference and Access to Social Insurance: Evidence from China's Rural Pension Program. *Population and Development Review*, *36*. https://doi.org/10.1111/j.1728-4457.2010.00317.x

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

Frost, M. D., Puri, M., & Hinde, P. R. A. (2013). Falling sex ratios and emerging evidence of sex-selective abortion in Nepal: Evidence from nationally representative survey data. *BMJ Open*, *3*(5), e002612. https://doi.org/10.1136/bmjopen-2013-002612

Frye, M., & Bachan, L. (2017). The demography of words: The global decline in non-numeric fertility preferences, 1993–2011. *Population Studies*, *71*(2), 187–209. https://doi.org/10.1080/00324728.2017.1304565

Fuchs, R. (2012). *The relative importance of education for the fertility decline in Sub-Saharan Africa*.

Galloway, P. R., Lee, R. D., & Hammel, E. a. (1998). Urban versus Rural: Fertility Decline in the Cities and Rural Districts of Prussia, 1875 to 1910. *European Journal of Population / Revue Européenne de Démographie*, *14*(3), 209–264. https://doi.org/10.1023/A:1006032332021

Javed, R., null, null, Mughal, M., & null, null. (2019). Have a Son, Gain a Voice: Son Preference and Female Participation in Household Decision Making. *The Journal of Development Studies*, *55*(12), 2526–2548. https://doi.org/10.1080/00220388.2018.1516871

Jiang, L., & O'Neill, B. C. (2017). Global urbanization projections for the Shared Socio-economic Pathways. *Global Environmental Change*, *42*, 193–199.

https://doi.org/10.1016/j.gloenvcha.2015.03.008

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

Kebede, E., Striessnig, E., & Goujon, A. (2022). The relative importance of women's education on fertility desires in sub-Saharan Africa: A multilevel analysis. *Population Studies*, *76*(1), 137–156. https://doi.org/10.1080/00324728.2021.1892170.

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.

Krishnan, V. (1991). Female labour force participation and fertility: An aggregate analysis. *Genus*, *47*(1–2), 177–192.

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. (2019a). 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

Lerch, M. (2019b). 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. (2017). Education empowers women to reach their personal fertility target, regardless of what the target is. *Vienna Yearbook of Population Research*, *15*, 27–31. https://www.jstor.org/stable/26506096

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

Lutz, W., Skirbekk, V., & Kabat, P. (2013). *How Education Drives Demography and Knowledge Informs Projections*. 29.

Ministry of Health and Population, N., New ERA, & ICF. (2022). *Nepal Demographic and Health Survey 2022*. Ministry of Health and Population, Nepal. https://dhsprogram.com/publications/publication-PR142-Preliminary-Reports-Key- Indicators-Reports.cfm

Saleem, S., & Bobak, M. (2005). Women's autonomy, education and contraception use in Pakistan: A national study. *Reproductive Health*, *2*(1), 8. https://doi.org/10.1186/1742-4755-2-8

Santelli, J. S., Song, X., Garbers, S., Sharma, V., & Viner, R. M. (2017). Global Trends in Adolescent Fertility, 1990–2012, in Relation to National Wealth, Income Inequalities, and Educational Expenditures. *Journal of Adolescent Health*, *60*(2), 161–168. https://doi.org/10.1016/j.jadohealth.2016.08.026

Shapiro, D., & Tambashe, B. (1999). *Fertility Transition in Urban and Rural Areas of Sub-Saharan Africa*.

UN. (2018). *World Urbanization Prospects—Population Division—United Nations*. https://population.un.org/wup/

UN. (2021). *World Urbanization Prospects—Population Division—United Nations*. https://population.un.org/wup/

United Nations. (2022). *World Population Prospects 2022: Summary of Results*. United Nations. https://doi.org/10.18356/9789210014380

U.S. Census Bureau. (2020). *International Data Base: Population Estimates and Projections Methodology*.

Vollset, S. E., Goren, E., Yuan, C.-W., Cao, J., Smith, A. E., Hsiao, T., Bisignano, C., Azhar, G. S., Castro, E., Chalek, J., Dolgert, A. J., Frank, T., Fukutaki, K., Hay, S. I., Lozano, R., Mokdad, A. H., Nandakumar, V., Pierce, M., Pletcher, M., … Murray, C. J. L. (2020). Fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100: A forecasting analysis for the Global Burden of Disease Study. *The Lancet*, *396*(10258), 1285–1306. https://doi.org/10.1016/S0140-6736(20)30677-2

Wittgenstein Centre for Demography and Global Human Capital. (2018). *Wittgenstein Centre Human Capital Data Explorer*. http://dataexplorer.wittgensteincentre.org/wcde-v2/

Wongboonsin, K., & Ruffolo, V. P. (1995). Sex preference for children in Thailand and some other South-East Asian countries. *Asia-Pacific Population Journal*, *10*(3), 43–62.

2 Thesis Articles

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

This article was originally published by the International Institute for Applied Systems Analysis in 20 April 2023 and also submitted to Asian population studies journal on 13 June 2023, which is currently under peer review, and is reprinted here with permission.

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

Abstract 3
About the authors 4
Acknowledgments 4
Introduction *5*
Research Question *10*
Data and Methods *12*
Results *16*
Conclusions and Outlook *25*
References *28*
Appendix *32*
Appendix A: TFR by education and rural/urban place of residence 32
Appendix B: Countries and survey years used in multilevel analysis 36

ZVR 524808900

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:

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

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

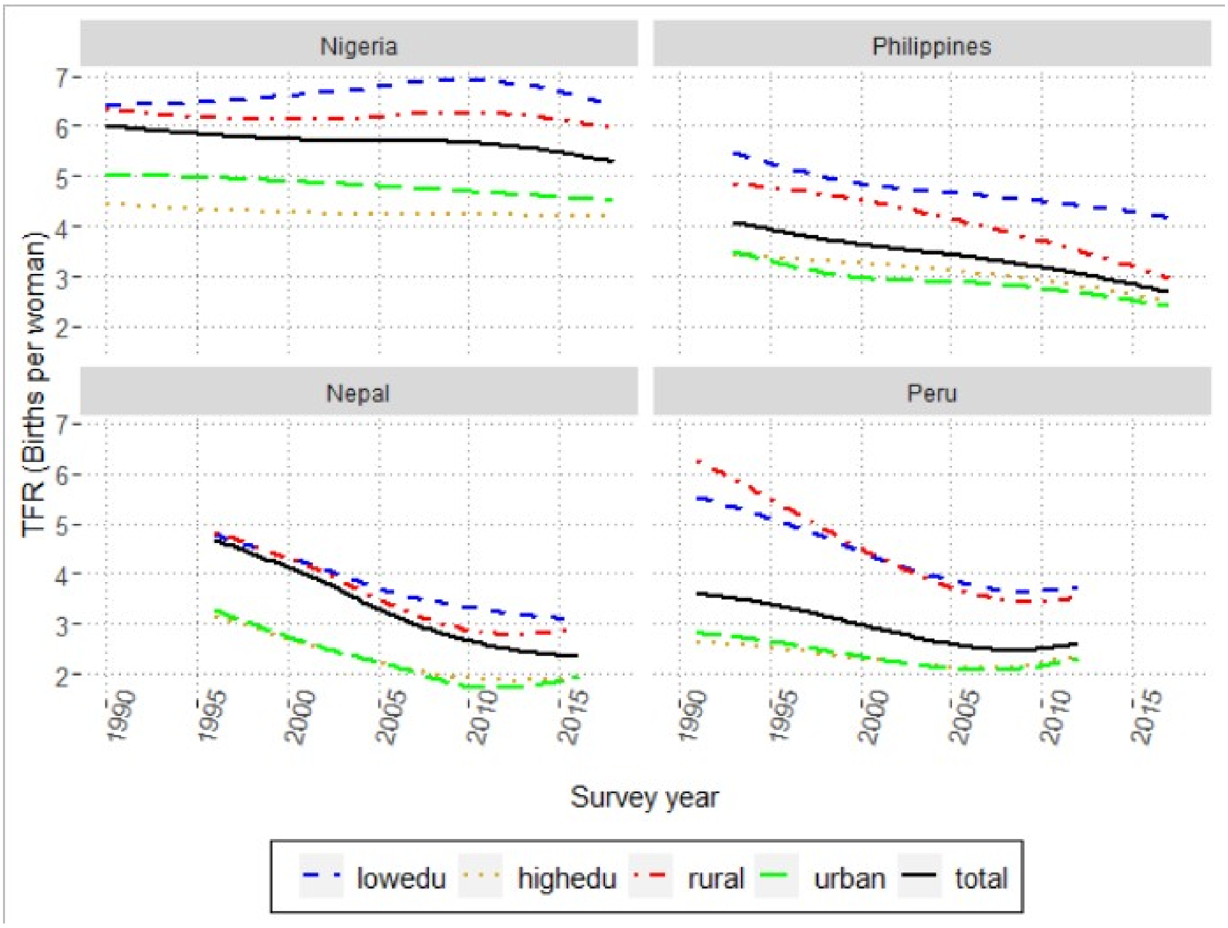


Figure 1: Trends in differentiated TFR between education and place of residence

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.

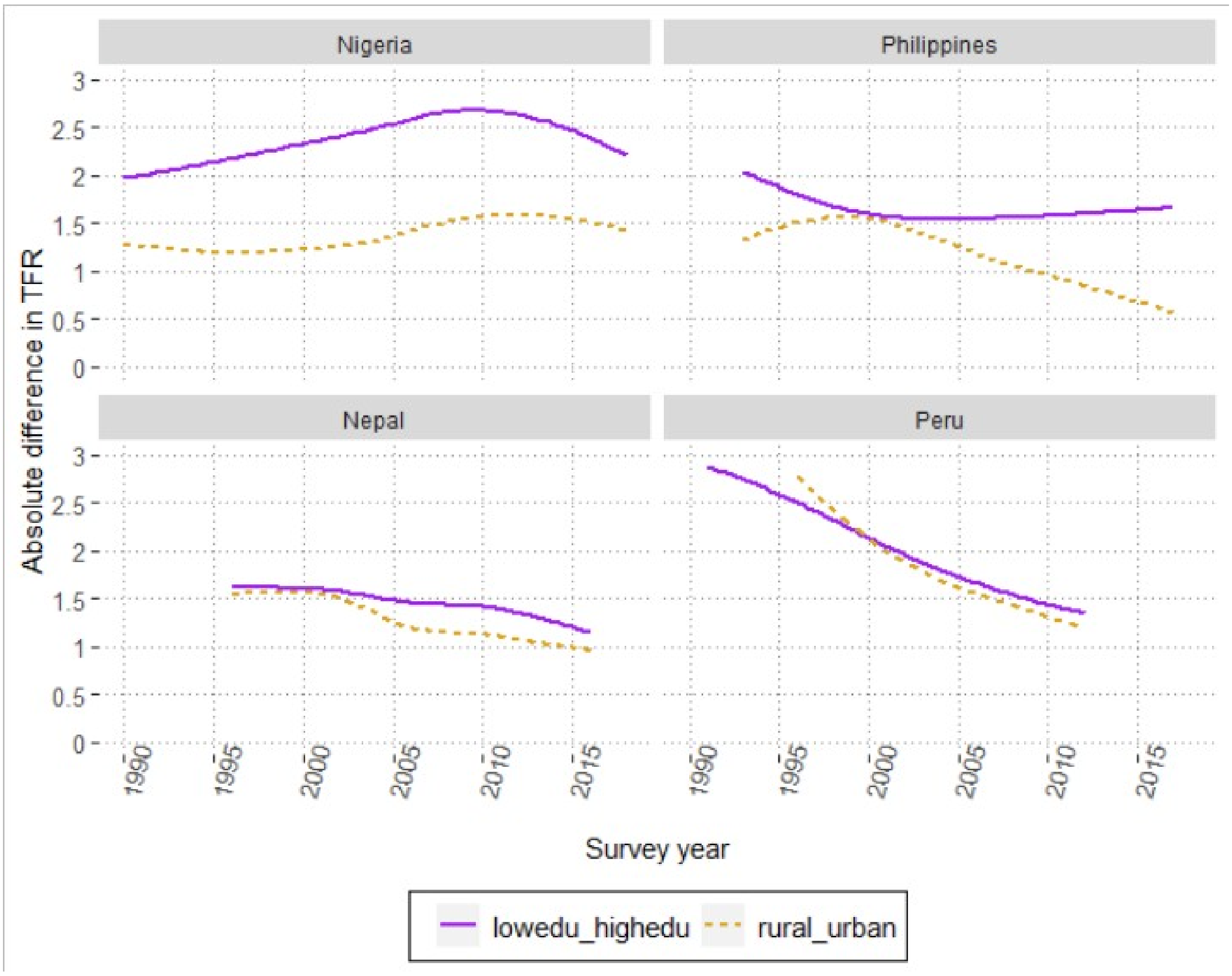


Figure 2: Trends in relative differential by levels of education & place of residence

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.

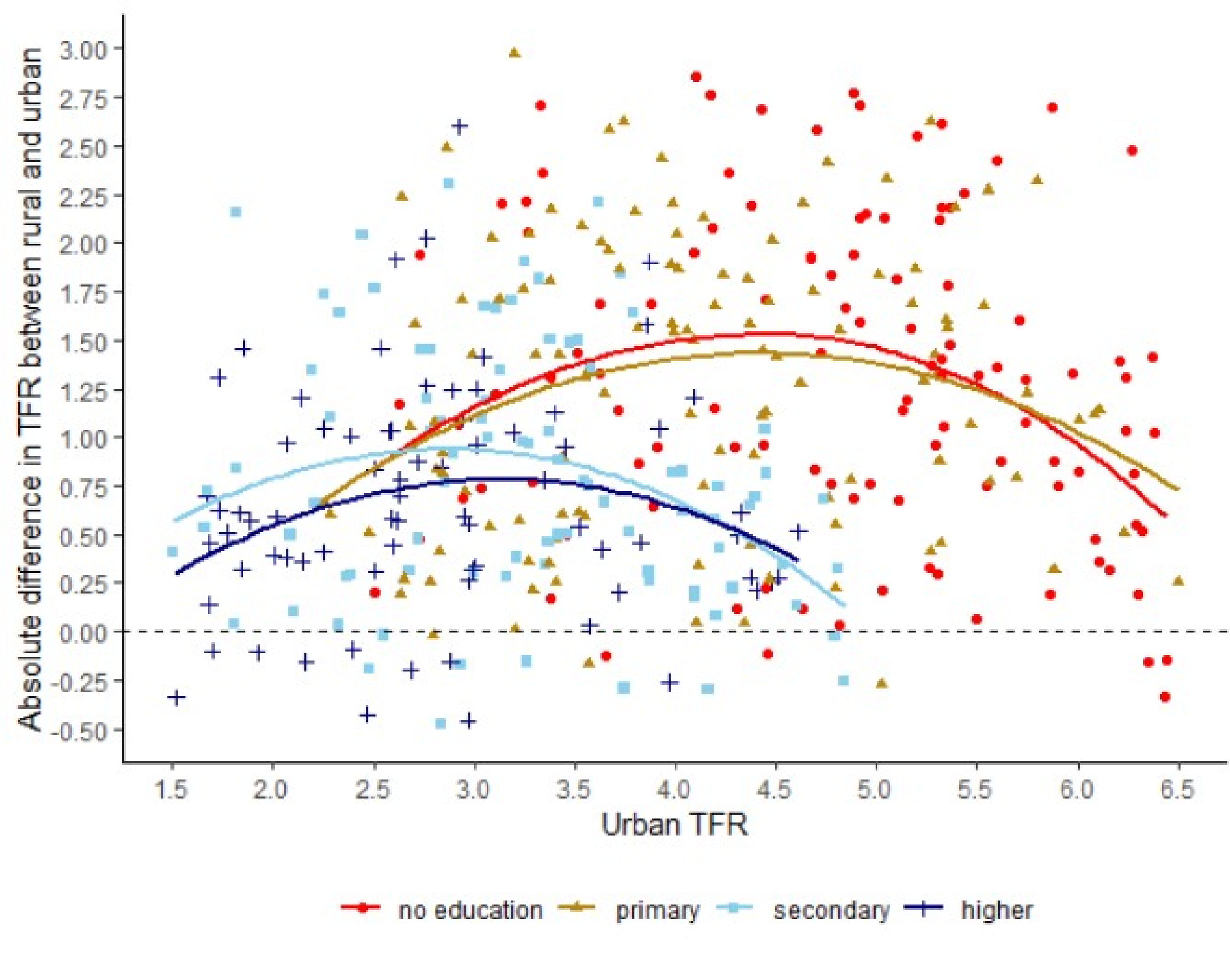


Figure 3: Global pattern of urban/rural differentials by the level of education (four categories) from 1990 to 2020

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.

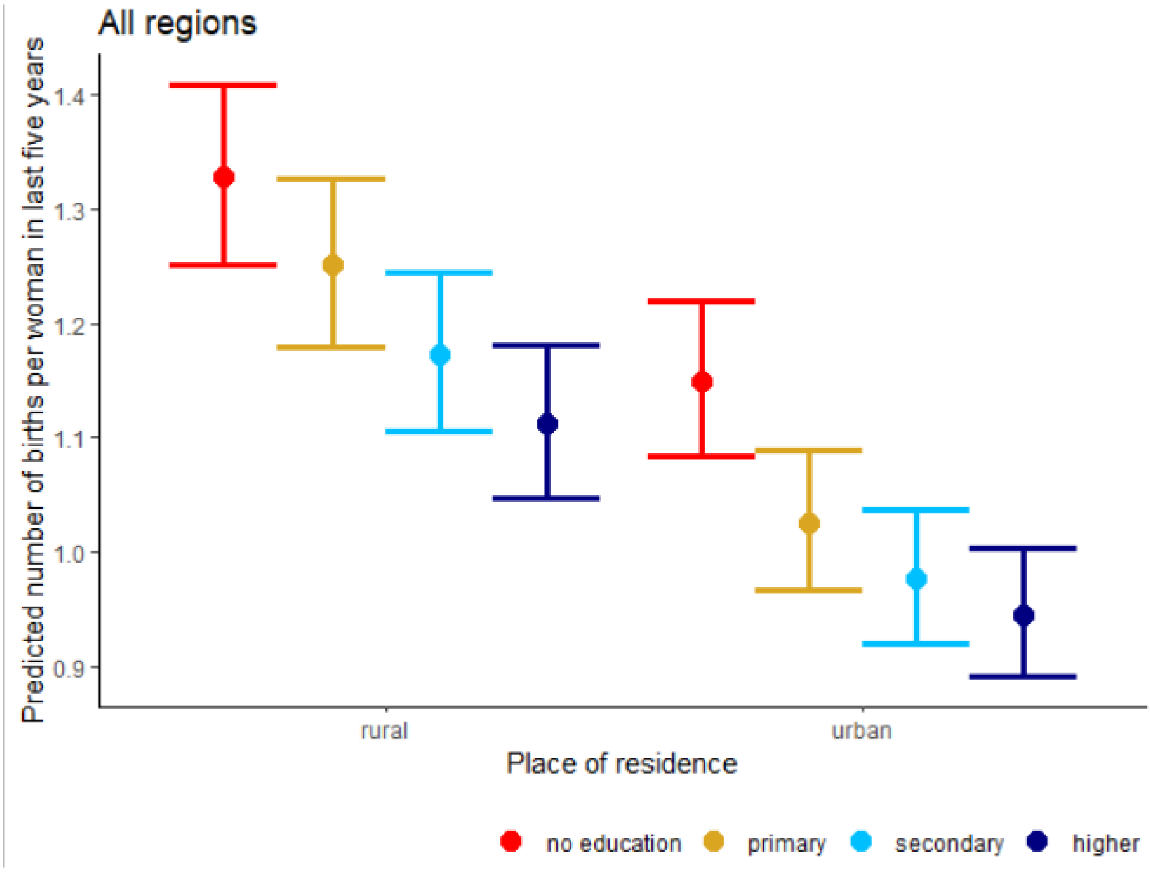


Figure 4: Predicted number of live births per woman within five years: all regions

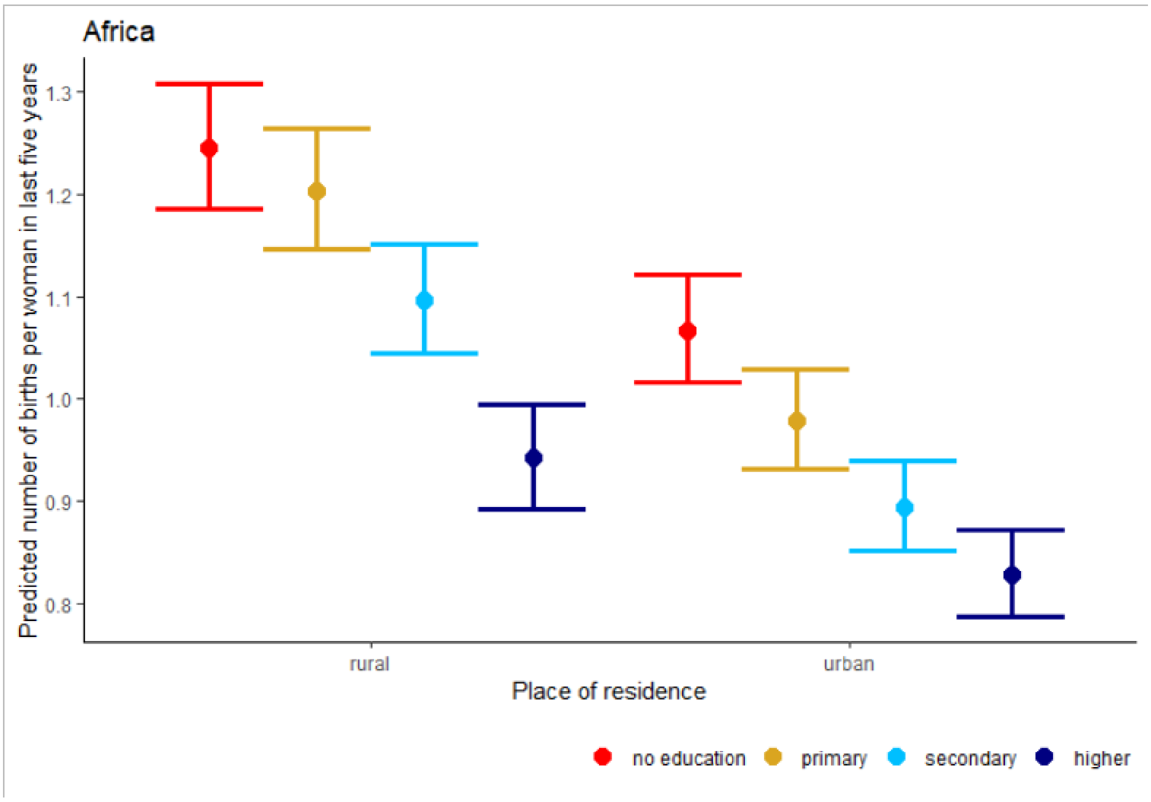


Figure 5: Predicted number of live births per woman within five years: Africa

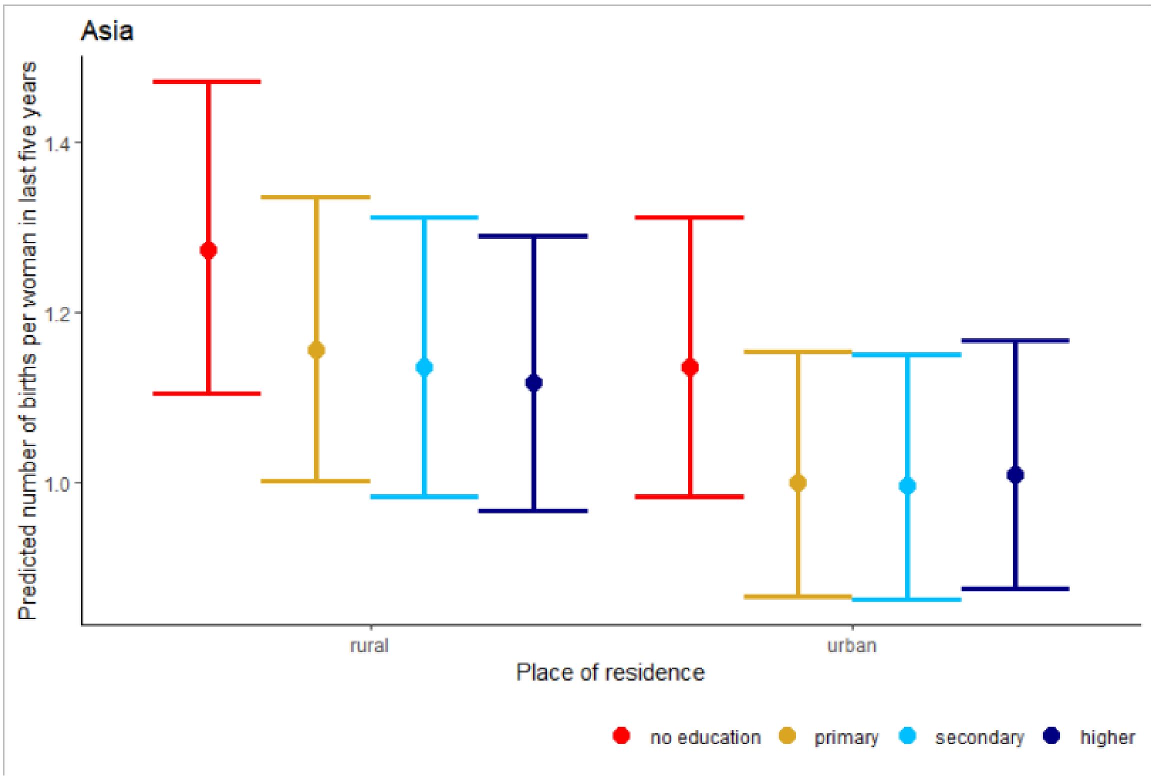


Figure 6: Predicted number of live births per woman within five years: Asia

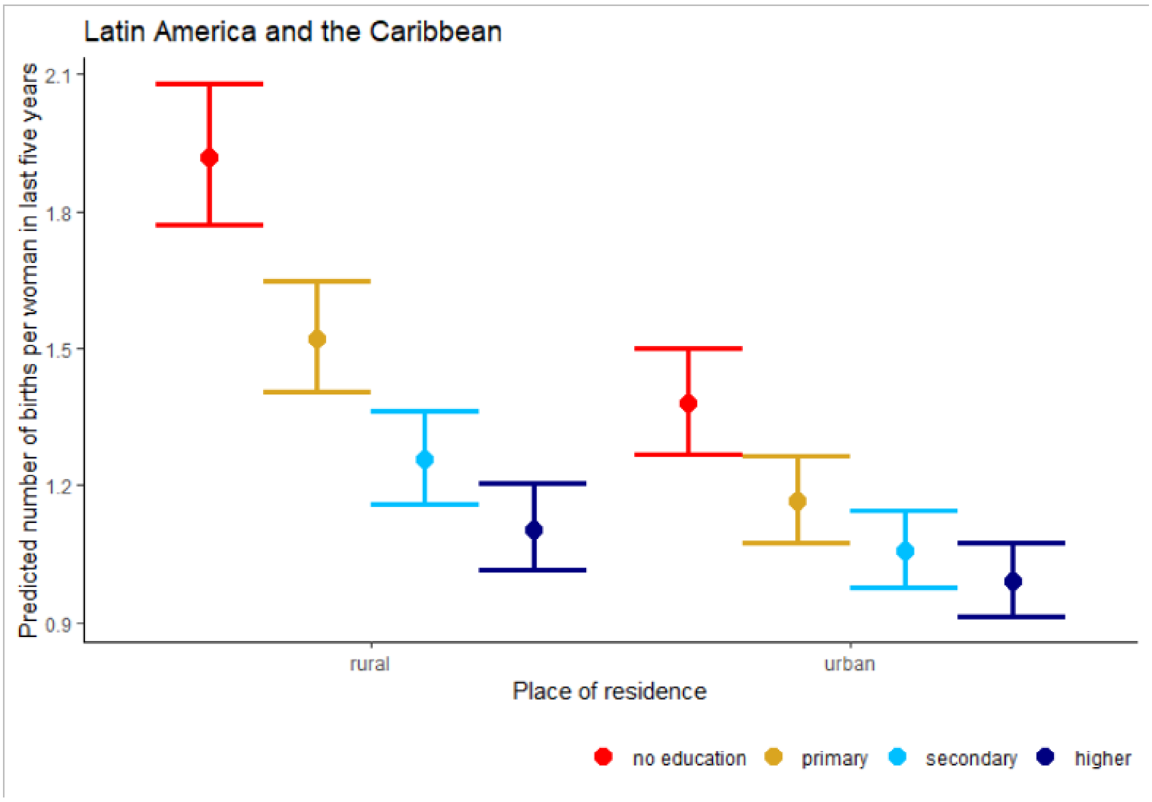


Figure 7: Predicted number of live births per woman within five years: LAC

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

2.2 Africa's fertility decline is partly driven by diffusion processes among education groups.

This article is submitted to Proceedings of the National Academy of Sciences journal on 17 November 2023, which is currently under peer review, and is reprinted here with permission.

Africa's Fertility Decline is Partly Driven by Diffusion Processes among Education Groups

Saroja Adhikari, Wolfgang Lutz*, Endale Kebede

Authors' Affiliations :

[1]International Institute for Applied System Analysis, Laxenburg, Austria, 2361

[2]Wittgenstein Centre for Demography and Global Human Capital, Vienna, Austria

[3]University of Vienna, Department of Demography, Vienna Austria,1020

Corresponding Author : Wolfgang Lutz[1*2*3] ,
Address: Schloßpl. 1, 2361 Laxenburg,
Phone Number: +43 2236/807 **294**
Email: lutz@iiasa.ac.at

Authors' contact Information :

Saroja Adhikari[1*2](sarojaadhikari2@gmail.com)
Wolfgang Lutz[1*2*3](lutz@iiasa.ac.at)
Endale Kebede[2*3] (endale.birhanu.kebede@univie.ac.at)

Classification:
Major: Social science
Minor: Demography Economic Sciences

Key words: Diffusion, Fertility, Africa, Projection, Education

Abstract

This paper integrates the extensive literature on diffusion processes in the fertility transition with that on female education and cognition-driven demographic transition and operationalizes this combination for practical use in population projections. It applies the concept of socially embedded fertility preferences through empirically assessing the effect of population heterogeneity by level of education on fertility. In addition to the purely compositional effect, it also includes social learning and diffusion processes from more educated to less educated women in the model.

Using all available Demographic and Health Surveys (DHS) data for African countries (including 1.03Mio cases), we assess the diffusion of both ideal family size and actual fertility at the level of sample clusters and strata by showing how the prevalence of higher educated women with lower fertility in the same cluster influences fertility of lower educated women. The results show strong diffusion effects for both fertility intention and behaviour. We combine these insights with recently estimated national-level time series of education-specific fertility trends in Africa, proposing a way for future fertility projections of heterogeneous populations differentiated by level of education.

Significance statement

Africa's population is forecast to more than double before 2100 due to the world's highest fertility rates. But the extent of future population growth, age structure and the associated social, economic and environmental challenges depend crucially on the speed of future fertility decline. While female education has long been identified as one of the key determinants of individual family size alongside the availability of reproductive health services, this study adds a powerful new argument for policies enhancing female education by pointing at the decisive effects of diffusion processes where less educated women in the same community follow the example of more educated women both in lowering their desired family size as well as in actually practicing family limitation.

Keywords: Diffusion, Fertility projection, Female Education

\Main text

Introduction and rationale

The world is currently going through a fundamental demographic transition from high and initially largely uncontrolled birth and death rates to low and controlled birth and death rates. Different populations are at different stages of this universal process that started in Northern Europe and France in the 19th Century and is still unfolding in most of Africa and parts of Western Asia. Typically, death rates began to decline before birth rates because people were ready to quickly move to newly available health interventions that helped them or their family members to survive, whereas reproductive behaviour has been much more deeply ingrained in traditional norms, cultural values and transmitted behavioural patterns and thus changes more slowly. During the period when death rates have already fallen, but birth rates are still high, there is population growth. In Europe and the US, this phase of demographic transition was experienced in the late 19th and early 20th Century. In most parts of Asia and Latin America, it was in the 1970s-80s, while Sub-Saharan Africa is currently in the midst of this process. The future of population growth in Africa will thus be the main determinant of future world population growth with the speed of future fertility decline in Africa being key.

While the concept of demographic transition is almost a Century old (1,2), there still is no consensus about what drives this universal process. In the most general way, it has been attributed to “demographic modernization”, a term that avoids a more specific identification of the determinants. While with respect to mortality decline, the differences in opinion mostly concern the relative role of nutrition and economic growth on the one hand and medical progress on the other, with respect to fertility, there have been essentially three broad explanations competing with each other: socioeconomic change, ideational change, and family planning programs (3).

This paper focuses only on fertility in Africa and primarily addresses the ideational, socioeconomic and behavioural implications of increasing female education. Based on the theoretical foundations of the concept of cognition-driven demographic transition (3,4), we took changes in the highest educational attainment of women as an empirical proxy and distinguished between fertility declines resulting from a purely compositional effect – an increase in the proportion of women with higher education and thus lower fertility – and that due to diffusion based on the concept of socially embedded fertility preferences (5).

Using the full set of 138 DHS surveys that have been carried out in Sub-Sharan Africa since the 1980s, including 1.03 Mio individual records of women aged 15-49, we group women into four different categories of educational attainment and study their education-specific ideal family size as well actual fertility at the level of 58708 sample clusters and 11873 strata relating this to the mean level of education in the respective cluster/stratum thus empirically assessing the degree of social embeddedness of reproductive behaviour.

In the final part of the paper, we use the insights gained from this analysis to advance a new method for forecasting education-specific fertility trends at the national level, which is an essential ingredient of multi-dimensional population projections by age, sex and level of education, which so far had to rely on an indirect method assuming trajectories of overall TFR that are subsequently broken down (6). The diffusion-based method advanced in this paper will thus be foundational for the future production and uptake of human capital projections for a broad range of applications ranging from assessing the consequences of population ageing in Europe and Asia (7) to the SSPs (Shared Socioeconomic Pathways) in climate change related studies (8).

Cognition-driven demographic transition and female education

In fertility analysis, it has become common to distinguish between the proximate determinants (such as frequency of intercourse, contraception or abortion) and socioeconomic determinants (such as the costs and benefits of children) (9). These different determinants operate at different levels and thus do not compete with each other in explaining fertility changes. For example, the realization of a lower desired family size for economic reasons can operate through the use of contraception. Recently, a third level of determination operating at the level of cognition has been suggested, referring to what happens in our minds/brains when we choose certain behaviors, including the degree of rationality and the acceptance and adoption of social norms and ideals we encounter in our environments. This third level of determination also includes what has been characterized as ideational change (10).

This concept of three levels of determination directly corresponds to the famous three prerequisites of a lasting fertility decline as identified by Ansley Coale (11) on the basis of insights from the Princeton European Fertility Project. The first of these stated prerequisites is that “fertility needs to be within the calculus of conscious choice”, which has been further elaborated by Van de Walle (12) under the title “Fertility Transition, Conscious Choice and Numeracy”. Cleland et al. (10) also point to ideational changes as the drivers of the fertility transition rather than changing economic conditions or contraceptive methods. These latter two levels of determination are captured by Coale’s two other stated preconditions, namely that lower fertility needs to be advantageous and that acceptable means for family limitation need to be available. Again, these three preconditions operate at different levels and need to be simultaneously met to result in a lasting fertility decline. But there still is discussion about which of these levels triggers change in the other ones.

The key role of cognition and ideational change in fertility decline is also reflected in the vast body of literature on education and reproductive behaviour (6). Consistent patterns of fertility differentials by mothers’ education have been found from medieval times to the present in virtually all countries and at very different stages of socioeconomic development (13). Typically, the empowering effect of education brings women in high fertility settings to want fewer children and find effective ways to have fewer children.

While there is robust evidence for a causal effect of female education on fertility (14), it is less clear which aspects of education cause these changes. Education tends to among other things lead to higher incomes and higher labour force participation – thus increasing the opportunity costs of having children – as well as to generally higher socioeconomic status. In developmental psychology, it has also been shown beyond any doubt that education alters the way we perceive the world, changes our planning horizon, and the degree to which we think abstractly and can imagine counterfactual scenarios, all things that matter for our choices and our behaviour. Hence, in the context of cognition-driven demographic transition, we see educational attainment primarily as an empirical proxy of changes in our way of thinking and cognition. Focusing on formal education also has the advantage that empirical data are widely available, including all the DHS data used in this study. Moreover, given the consistently strong educational differentials in most aspects of human behaviour, educational attainment categories have also been called the single most important source of observable population heterogeneity (15). This is also the justification for using educational attainment categories as this study's primary source of empirically assesses social stratification (FN1).

These pervasive education differentials have also been incorporated into models of population dynamics that stratify populations not only by conventional age and sex but also by levels of education. Female education leads to both lower fertility and lower child mortality, which have opposite effects on population growth. But in most situations, the fertility factor by far outweighs the higher child survival with better female education, leading to a sizable long-term reduction in the population growth rates. A quantification of this purely compositional effect of education has shown that when assuming identical sets of education-specific fertility trajectories for the first half of the 21st Century for all countries, a scenario assuming constant school enrollment results in a world population size that is one billion higher by 2050 than under a scenario of rapid school expansion (15). With respect to the global Sustainable Development Goals (SDGs), it has been shown that meeting the goals relating to education (SDG4) and health (including reproductive health, SDG3) would result in significantly lower world population growth than otherwise expected (17). However, all these results are only based on estimating the compositional effect of education due to higher proportions of women with more education. In the following, we will show that there is reason to assume an additional strong effect on fertility of diffusion processes from more highly educated women to those with less education.

Diffusion of norms and behaviour

Human beings are inherently social creatures, and their behaviour is strongly influenced by the actions and attitudes of others within their society. This phenomenon arises from a fundamental need for social interaction and acceptance. Individuals seek conformity or validation for their behaviour from their peers, family, and community members (18). The collective behaviour that emerges from these interactions is often regarded as social norms, which serve as guidelines for acceptable conduct within a given society (19). These norms shape various aspects of human behaviour, including social roles, etiquette, values, and even personal beliefs and decisions. The desire for social conformity and the validation of one's actions from others are integral aspects of human socialization, allowing individuals to establish a sense of belonging and maintain social cohesion within their communities.

The field of demography has long explored the impact of social interactions on reproductive decisions and behaviour. However, most studies have primarily focused on contraception and its acceptance through social learning (20–22) and qualitatively looked at the stated social influence on fertility intentions (23). Less attention has been given to quantitatively capturing such social learning on the idealization and behaviour surrounding human reproduction at the individual level (24, 25). In 2001, the National Research Council published an assessment, "Diffusion Processes and the Fertility Transition," summarizing the literature and pointing out

[1] Footnote: Recent studies have also tried to quantitatively adjust indicators of mean years of schooling by actually tested adult skills in the form of SLAMYS (skills in literacy adjusted mean years of schooling) (16). This comes closer to directly measuring cognitive capacity than stating the years of formal education which may differ in quality and content from one school system to another.

that most of the studies in the field focus more on how diffusion occurs rather than what actually diffuses (26).

The question of what is being disseminated also depends on what is being measured as outcome variables. In this study, we focus on stated family size ideals and actual realized fertility. While ideals are obviously subject to ideational change and diffusion of such changes, including the broader cognitive changes discussed above, the latter also include more practical aspects such as the availability and use of contraception and biological factors such as fecundability. The fertility transition process, as described above, encompasses changes in both the transition to lower normative fertility ideals and norms about methods to realize such fertility outcomes. Diffusion processes are likely to play an important role in all of these changes through interactions and social learning in which, typically, the ideational norms and behavioural patterns of the more educated avant-garde tend to be adapted successively by the less educated groups.

Another line of research from an economics background addresses the issue of diffusion of fertility and, in particular, the preferences behind behavioural changes in a framework of socially embedded fertility preferences (5). It focuses on the transition between different equilibria of high ideal and actual fertility and low ideal and actual fertility. It is assumed that reproductive decisions are not only a private matter but that they are also subject to social mores, which in turn are influenced by family experiences and the cultural milieu (27,28). They discuss two distinct social preference classes that play a role in the transition and diffusion from larger to smaller family sizes. The "competitive" group, also known as "trendsetters" or "innovators," aims for a higher social status relative to others and chooses to have fewer children. On the other hand, the "conformist" group, also referred to as "adopters" in diffusion theory – following Rogers (1995) – desires to align with societal norms and adopt behaviours they see as the new social ideal. This view is also in line with the literature on developmental idealism (28).

In this paper, based on the existing empirical evidence and theory, we hypothesize that lower fertility behaviour emerges among higher educated women who are ahead of others in recognizing the advantages of having a smaller family. We follow Bongaarts & Watkins (25), who suggested that apart from socioeconomic determinants, fertility declines are accelerated by social interaction in close geographical or social proximity. Through this mechanism, lower fertility ideals and subsequent behaviors then diffuse to less educated women living close to more educated women. In our analysis, we further differentiate the pattern by not just looking at two groups but at four different groups of women as defined by their educational attainment since we have large international data sets allowing for such differentiation.

Results from DHS

Figure 1 shows on the right-hand side the estimated relationship between ideal family size as stated by the 1.03 million ever-married women aged 15-49 in all African DHS surveys pooled together and differentiated by the highest educational attainment category of the woman (no education, primary, secondary and higher) and plotted against the average level of education (Mean Years of Schooling) of all women in the same sample stratum (group of several smaller clusters). There are 11873 such strata in this data set.

The result shows the expected apparent differentiation of ideal family size by level of education and a less expected very strong decline within each education category with increasing average education in the sample stratum as plotted on the x-axis. The registered average ideal family size for women without formal education varies from around seven children in strata with very few educated women to only around 4.5 children in those with high proportions of more educated women, as captured by high mean years of schooling. For women with primary and secondary education, the lines are lower but have a similar slope. This surprisingly strong effect of the presence of more educated women with lower fertility preferences in the same living environment on the stated preferences of women with a given individual education can be seen as a clear indication of the presence of strong diffusion effects in fertility preferences. Viewed differently, the strong decline of, e.g., the green line indicates that the ideal family size of women with secondary education in an otherwise uneducated environment is about 50 per cent higher than in a highly educated environment. Interestingly, even for the typically very few women with post-secondary education, the stated fertility preferences vary greatly depending on their environment.

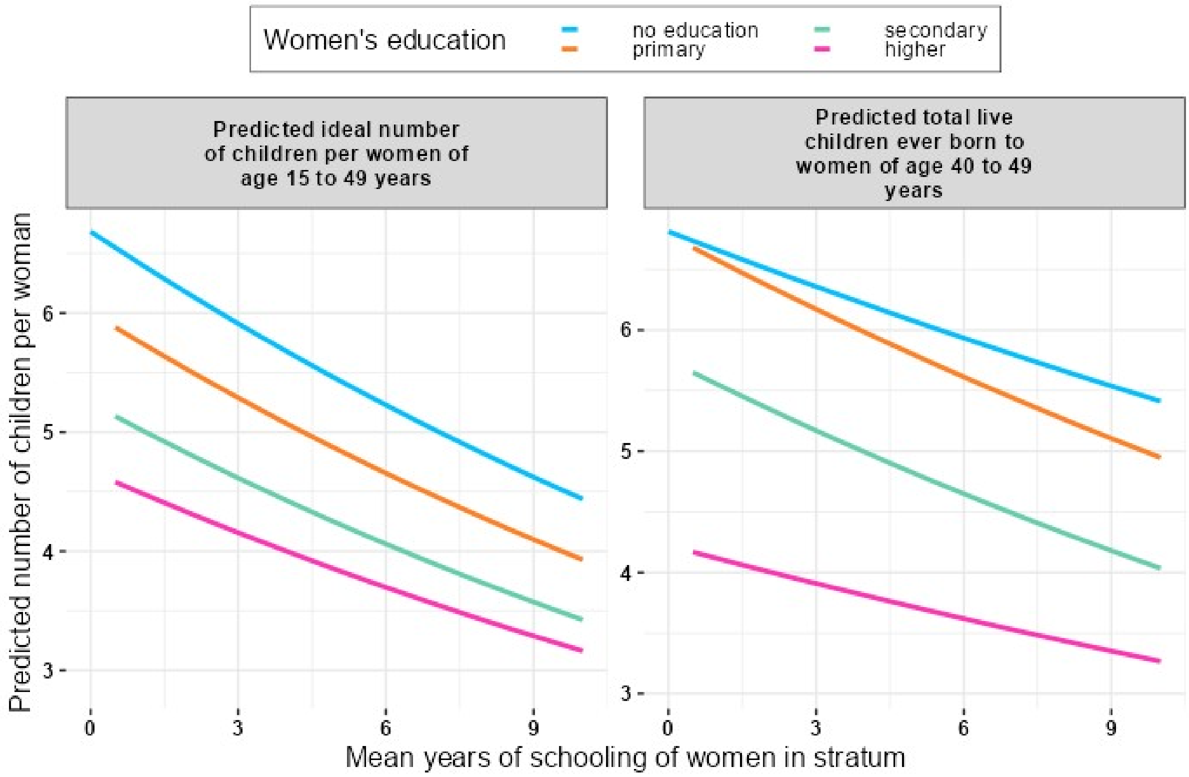


Figure 1: Mean years of schooling for women in a stratum vs. predicted ideal number of children per woman (left) and predicted number of live children ever born to women aged 40-49 (right) for women of four different educational attainment groups for all available African DHS countries (latest round available)

This finding indicates a strong diffusion effect in the stated ideal family size which also is very robust, as confirmed by extensive sensitivity analyses documented in the supplementary information (SI). In particular, a possible counterhypothesis is addressed, namely that ideal family size and mean years of schooling in the same cluster are jointly determined by a third factor, with degree of urbanization being an obvious candidate. However, after controlling urban/rural places of residence, the resulting pattern remains virtually unchanged from that shown in Figure 1. The same is true after controlling for other socioeconomic factors and limiting the sample only to the most recent set of DHS for each country. It also remains very similar for a longitudinal analysis within the same countries. All these different ways of studying this massive set of DHS data consistently confirm quantitatively very strong diffusion processes in ideal family size where the effect of the education of the immediate living environment can be even stronger than personal education being one category higher.

Does the same pattern as identified for ideal family size also hold for actually realized fertility? Figure 1b (right-hand side) has the same structure as 1a, with the variable on the y-axis now being the number of live children ever born (live births) to women aged 40-49. Since there is a complex interaction between education and the timing of fertility over the life course, here we decided to focus on the quantum of fertility as approximated by this indicator. The results show an even stronger differentiation by the level of mothers' education, in particular for the highest education groups. In a low educated environment, there seems to be little difference between the realized fertility of uneducated women and women with primary education. In contrast, secondary and higher education in such environments lead to significantly lower fertility. With increasing education in the environment, actual fertility becomes consistently lower.

What could be the reason for this difference between the ideal and actual fertility of highly educated women with respect to the influence of the social environment? An extensive body of literature (30–32) consistently indicates that higher education empowers women to achieve their family size goals better. This empowerment of women can operate through various channels ranging from easier access to contraceptives to being able to better pursue their own preferences vis a vis those of their husbands or extended family (33–35). On top of this individual level effect, there is an apparently strong diffusion process with respect to realized fertility.

Discussion and application to national level projections

How can these important insights about strong diffusion effects assessed at the level of sample clusters and strata be utilized to derive assumptions for education-specific population projections? The first obstacle to doing this is that population projections are typically carried out at the national level. One would expect that diffusion processes at the national level are less pronounced than at the cluster level because there is less intensive interaction and social learning than within the immediate living environment. To investigate this expected difference quantitatively, Figure 2 gives an isomorphic analysis to Figure 1 using the same DHS data set with the only difference that ideal family size and mean years of schooling are assessed at the level of entire countries rather than sample strata. The appearing pattern clearly confirms our expectations in the sense that differences resulting from individual level education are being maintained and that the influence of diffusion at the national level also results in a clear negative slope, which is, however, less pronounced than at the stratum level shown in Figure 1a. Again, for the example of secondary education, women living in a largely uneducated country have about a 30 per cent higher ideal family size than those living in a highly educated country, as compared to 50 per cent when assessed at the stratum level. This entirely expected pattern in which the extent of the diffusion effect declines with the increase of the unit at which it is assessed – presumably reflecting less intensive interaction – further confirms diffusion's relevance in the fertility decline process.

Another potential problem in trying to translate the DHS based findings into an operationalized model for fertility forecasting is the fact that the analysis presented so far is based on cross-sections as well as pooled data of cross-sections at different points in time but does not allow for consistent analysis of time-series alone due to the irregular pattern of DHS survey dates in different countries. Fortunately, a new set of national level time-series data for education-specific fertility rates in most African countries since 1980 has become available recently (36). Using Bayesian methods, this new data set uses education-specific information from all available DHS to estimate consistent time series in 5-year intervals that are also consistent with the UN estimates of overall fertility levels for 32 African countries. Combined with the reconstruction of educational attainment levels by age and sex for all countries in the world as given by the Wittgenstein Centre for Demography and Global Human Capital, these new data allow for a consistent time-series analysis of the national level association between education-specific fertility trends and changes in the mean years of schooling of the reproductive age female population.

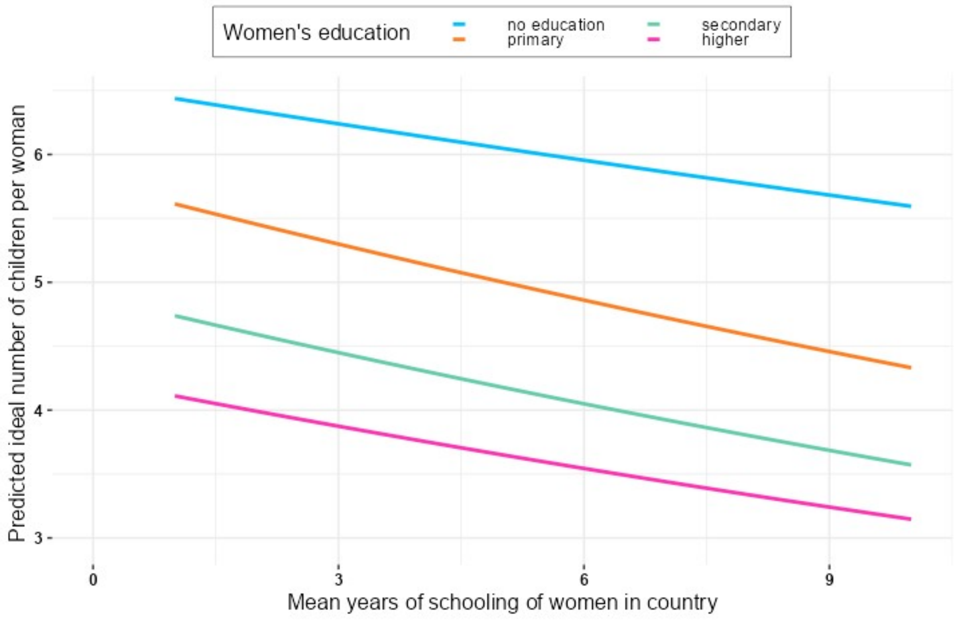


Figure 2: National level analysis across 39 African countries: Mean years of schooling for women in reproductive age in a country vs. predicted ideal number of children per woman in four different educational attainment groups, from 1980 to 2022.

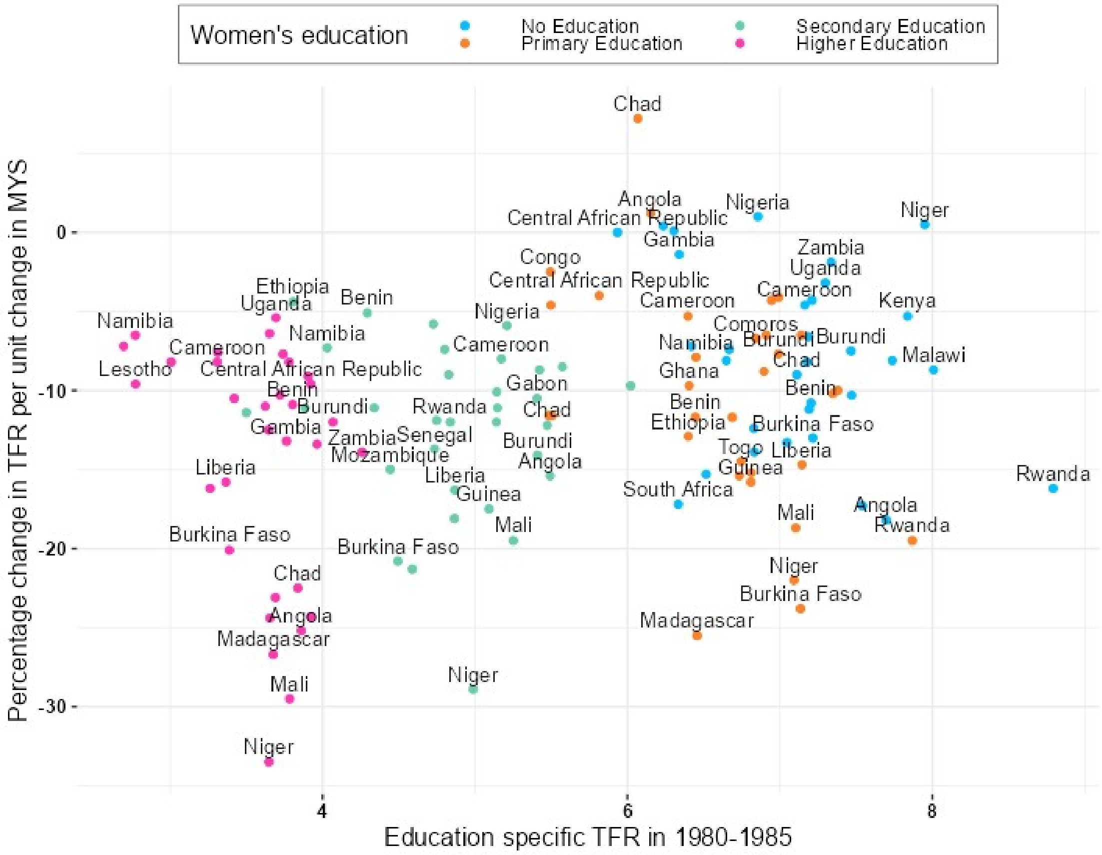


Figure 3: Percentage changes in TFR per unit change in MYS, 32 African countries 1980-85 to 2010-15, differentiated by four educational attainment categories and plotted against the level of education-specific Total Fertility Rates in 1980-85.

Figure 3 summarizes these time-series data for 1980-85 to 2010-15 to show the percentage change in TFR per unit change in mean years of schooling for four education groups against the initial fertility level in 1980-85 of the respective education groups for all individual countries. The figure shows that across all four education groups and all countries and times on average, an increase in education in the national environment of one year was associated with a 12 per cent (11.8 per cent unweighted and 13.04 per cent population weighted) decline in TFR. This again, is the assumed diffusion effect on top of the composition effect based on individual education levels. This quantification of the diffusion effect differs somewhat by level of education. When population weighted, the effect is, on average 9.3 per cent decline in fertility for one year more in national-level education for uneducated women, 11.3 percent for women with primary education, 12.4 per cent for those with secondary and 14.3 per cent for women with higher education.

While the pattern in Figure 3 also visually confirms the impression of a somewhat stronger relative fertility decline for more educated women (in absolute terms, the TFR decline is mostly stronger for the low education groups), there is considerable national variation. In particular, it is apparent that the most highly educated women in countries with very low overall education, such as Mali and Niger, show the strongest relative decline. This is likely to be a consequence of the fact that overall education has hardly improved in those countries over time, but the individually empowering effect of higher education on women's personal number of children has evidently increased over time.

How can these findings now be translated into projections of national level time-series of education-specific fertility? One way is to apply the estimated percentage changes as described above to projections of the future mean years of schooling as given by the WIC human capital projections. These human capital projections for all countries in the world follow three different scenarios as defined in the framework of the SSPs (Shared Socioeconomic Pathways) as widely used in the climate change research community to capture different future mitigative and adaptive capacities (37,38). We use the projected mean years of schooling for women of reproductive age as they are forecast under the rapid development (SSP1) scenario, the medium (SSP2), and the stalled development (SSP3) scenario. The future changes in mean years of schooling forecast under these scenarios are then applied to the most recent empirical education-specific fertility rates by using the above estimated average percentage changes in education-specific TFR resulting from a unit increase in mean years of schooling. The results are depicted in Figure 4 for the example of Kenya.

In the 1970s, Kenya was the country with the highest overall fertility rate in the world, as given by the World Fertility Survey (39), with a level above eight children per woman and the vast majority of women without formal education. Kenya has also been the subject of important studies highlighting the importance of diffusion in fertility and contraceptive use (20). Another interesting pattern of the education-specific fertility trends is the evident stall of the fertility decline of uneducated women around the year 2000, which was much more moderate for the more educated women. This fertility stall in many African countries has widely been discussed in the literature (40–44).

For readability, Figure 4 only includes two education groups (no education and secondary education) with information on the other groups as well as other countries in the SI. Up to 2015, empirically estimated education-specific fertility rates (36) are given, and beyond that, the forecasts following the SSP scenarios are presented. Since the stalled development scenario SSP3 assumes virtually no further improvements in female education, the resulting future decline based on the above estimated national level diffusion effects is minimal, and the lines are essentially flat. On the other extreme, the rapid social development scenario SSP1 assumes a very rapid education expansion (essentially following the SDG target of universal secondary education by 2030 with a trigger-down effect on tertiary education), resulting in a massive increase in the mean years of schooling of reproductive age women and in consequence a very rapid decline in education specific TFRs due to the assumed diffusion effects.

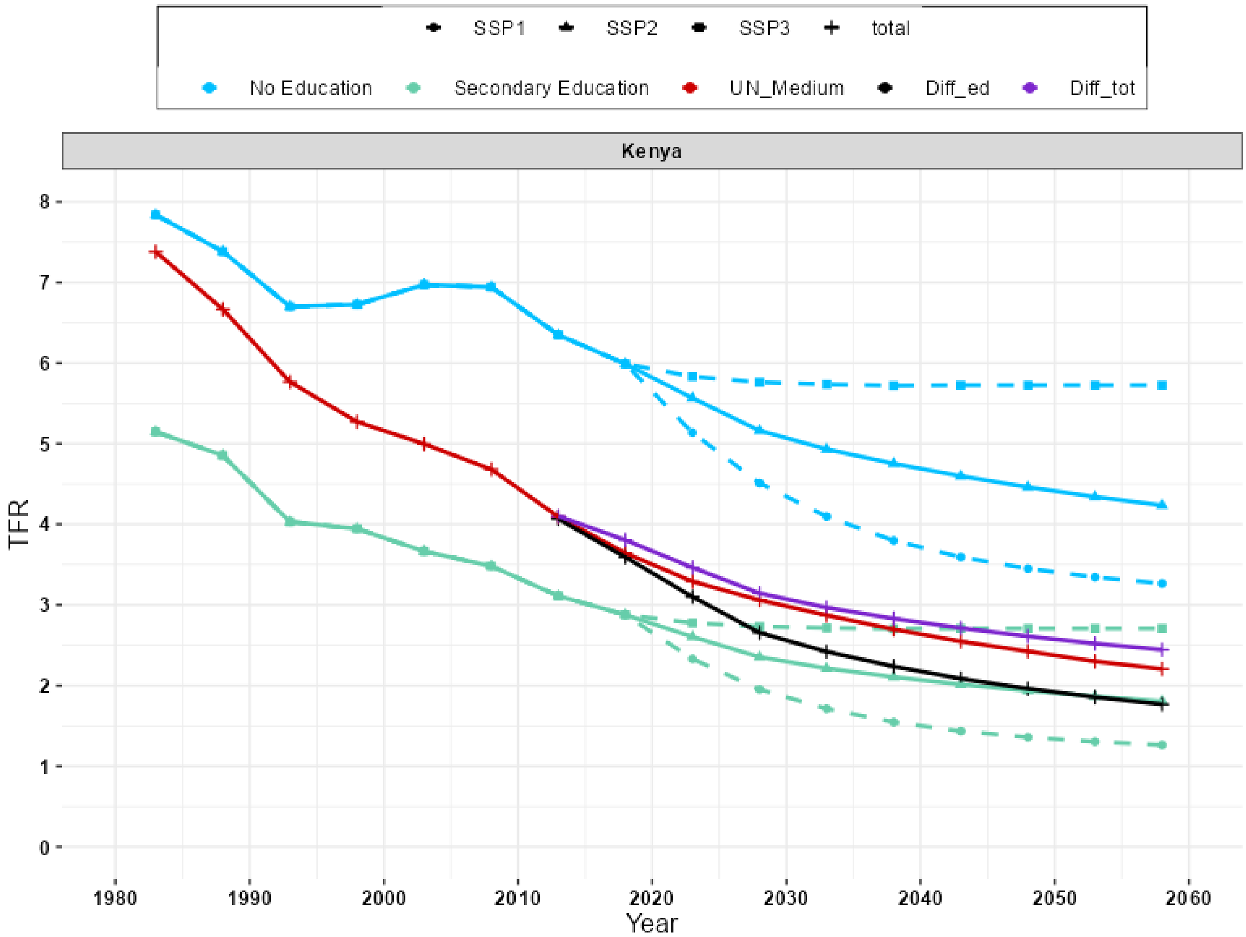


Figure 4: Past and projected trends in overall and education-specific Total Fertility Rates (TFR) following the SSP scenarios for the case of Kenya. The red line gives the UN estimates and projections of the overall TFR. The purple line (Diff_tot) gives the projections resulting from applying the estimated average diffusion effects to the 2010-15 empirical overall TFR (without differentiating by level of education) and the black line (Diff-ed) shows the projections resulting from applying the average diffusion effect to education-specific TFRs (for four education levels) and aggregating them to overall TFRs also reflecting the changing proportions of different education groups (composition effect) according to the SSP2 (medium) education expansion scenario.

Figure 4 also shows three lines for overall TFRs as provided by the UN estimates and projections (based on their model that does not differentiate by level of education) and the other ones resulting from the operationalization of the diffusion effect as introduced in this paper. To arrive at the overall TFR ("Diff_ed") at each point, the estimated and projected education specific TFRs are weighted with the proportion of women in the different education categories as given by the Wittgenstein Centre data set. This line is labelled "Diff-ed" and results in overall TFR levels over the coming decades that are somewhat lower than the UN medium variant. Alternatively, another TFR line labelled "Diff-tot" applies the diffusion effect directly to the overall TFR as given in the starting year, without differentiating by level of education. Hence, in this case, the resulting fertility decline is only driven by diffusion – as implied by the increase in mean years of schooling and the average diffusion effect – and does not include the additional composition effect. As expected, the resulting TFRs only based on average diffusion turn out to be a bit higher than the "Diff-ed" line that also includes the compositional effect. Interestingly, this line also lies a bit above the UN medium variant, which is based on statistical extrapolation of past overall TFR trends not differentiating by education composition and diffusion.

While this exercise shows the general feasibility to translate the estimated diffusion effect into education-specific fertility forecasts consistent with different education scenarios, several points still require further analysis and exploration before the method can be broadly applied. The first involves interpreting the trends in ideal and actual fertility in the highest education group. If we were to strictly focus on the diffusion from higher to lower education groups, the highest group should be seen as the avant-garde, whose own trend should hardly be affected by diffusion. However, the empirical analysis clearly shows that fertility in this highest group also declines as a function of increasing mean years of schooling in the cluster. It is plausible to assume that highly educated women in a largely uneducated cluster behave differently than in the case where most other women they interact with are also highly educated. There can be a reinforcing effect with feedback from the average behaviour. Dasgupta (27) speaks of conformist behaviour when the family size that each household desires is positively related to the average. This kind of feedback from the average requires further analysis but is already partly included in the design of this study by using average education in the cluster rather than the relative sizes of the different education groups. This design is partly for convenience since plotting the relative sizes of four groups on one axis would be difficult. But it can also help to capture this relationship to the average.

Finally, one may ask why we presented both the DHS based analysis at cluster and stratum level and then separately the national level analysis. The answer is that for theoretical reasons, we needed to establish the diffusion effect at the cluster level, where social learning is assumed to happen in close geographic and social proximity (25). Thus, it was important to establish a diffusion effect at this level. The transition to national level analysis was made for purely practical reasons since this is the level at which national time series are available, and projections are typically made. Since there is clearly less geographic and social proximity at the national level than at the cluster level, the expected diffusion effect is weaker. And this is what the data show. Yet, since projections are made at the national level, this weaker national level diffusion effect was incorporated into the forecasting model.

Materials and Methods

We combined individual-level information from demographic and household surveys with national-level data on educational attainment and education-specific fertility rates. Our analysis pools relevant data on 1.03 million ever-married women aged 15-49 from 138 DHSs collected in 39 sub-Saharan African countries over the years 1986–2022. In each country, the DHS surveys made use of a two-stage cluster sampling design and standard questionnaires to collect comparable nationally representative data on demographic, socio-economic, and health characteristics of eligible women of reproductive age (15-49) (further details are available in Rutstein and Rojas 2006).

Ideal fertility in DHS data indicates the number of children women (15-49) idealized to have in their lifetime regardless of how many children they have had or can have. On the other hand, actual fertility is measured by the total number of live births women aged 40-49 (sample= 257,037) say they had over the course of their lives. This analysis focused specifically on ever-married women who provided numerical responses regarding their ideal and actual fertility, allowing us to quantitatively examine fertility ideals and behaviors within the context of marriage. Non-numerical responses were excluded from our analysis to ensure accurate interpretation during the quantitative analysis.

The study evaluated the importance of diffusion in the fertility transition and operationalized it to population projections using three main steps. Firstly, the diffusion of family size (both ideal and actual) at a strata level was examined by demonstrating how the prevalence of higher-educated women impacts the fertility of lower-educated women residing in the same strata[2]. This was accomplished by fitting fixed-effect Poisson regression models and estimating the association between individual family size and the mean years of schooling at the strata level. The predictors in the analysis are strata-level mean years of schooling (MYS), individual education (classified as no formal education, primary education, secondary education, and higher education), and the interaction between the two. For each education group, we predict education-specific family size at different level of strata level mean years of schooling. [The details of the different model specifications and numerical results are given in SI Appendix].

Second, we estimate the education specific “diffusion rate” -as defined as the percentage change in education - specific TFR for a unit change in national level mean years of schooling over the period 1980/85-2010/15. This involved combining recently available national-level time-series data for education-specific fertility rates from many African countries (35) with data on MYS obtained from the Wittgenstein Center reconstruction of educational attainment by age and sex [The details of the estimation procedures and results are provided in the SI appendix].

Finally, we apply the estimated education-specific diffusion rates (step 3) to the projected mean years of schooling by the WIC human capital projections under the three so-called shared-socio economic pathways scenarios (SSP1, SSP2, SSP3)[3], and calculate the national level time-series of education-specific fertility for the subsequent years [see the details of the calculation in the SI Appendix].

Acknowledgment and funding

---

[2] Strata is a collection of sample clusters (the smallest geographical or administrative unit used as the primary sampling unit in the survey design). To adequately address spatial and social proximity, we based the analysis on 58708 clusters and 11873 strata. The average sample size within each cluster was 27, ranging from 1 to 1539. Because of partly very small cell size, the analysis presented in this document was mostly carried out at the stratum level where the average sample size was 280 women.

3 The SSPs (Shared Socioeconomic Pathways) are scenarios widely used in the climate change research community based on narratives describing alternative socio-economic developments, including future mitigative and adaptive capacities.

References

1. Landry A. La révolution démographique. Études et essais sur les problèmes de la population. Paris: Recueil Sirey; 1934.

2. Thompson W. Population. Am J Sociol. 1929;34(6):959–75.

3. Lutz W. Advanced introduction to demography. Northampton: Edward Elgar Publishing; 2021. (Elgar advanced introductions series).

4. Lutz W. Cognition-driven demographic transition [Internet]. N-IUSSP. 2022 [cited 2023 Oct 16]. Available from: https://www.niussp.org/fertility-and-reproduction/cognition-driven-demographic-transition/

5. Dasgupta A, Dasgupta P. Socially embedded preferences, environmental externalities, and reproductive rights. Popul Dev Rev. 2017 Aug 3;43(3):405–41.

6. Lutz W, Butz WP, KC S, editors. World population and human capital in the twenty-first century [Internet]. First edition. Oxford, United Kingdom ; New York, NY: Oxford University Press; 2014. 1056 p. Available from: http://ukcatalogue.oup.com/product/9780198703167.do

7. Marois G, Bélanger A, Lutz W. Population aging, migration, and productivity in Europe. Proc Natl Acad Sci. 2020 Apr 7;117(14):7690–5.

8. O'Neill BC, Kriegler E, Riahi K, Ebi KL, Hallegatte S, Carter TR, et al. A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Clim Change. 2014 Feb;122(3):387–400.

9. Bongaarts J. A framework for analyzing the proximate determinants of fertility. Popul Dev Rev. 1978 Mar;4(1):105–32.

10. Cleland JG, Wilson C. Demand theories of the fertility transition: an iconoclastic view. Popul Stud. 1987;41:5–30.

11. Coale AJ. The demographic transition. In: IUSSP, editor. International Population Conference. Liege, Belgium: International Union for the Scientific Study of Population; 1973. p. 53–72.

12. Van de Walle E. Fertility transition, conscious choice, and numeracy. Demography. 1992;29(4):487–502.

13. Skirbekk V. Fertility trends by social status. Demogr Res. 2008 Mar 28;18(5):145–80.

14. Lutz W, Skirbekk V. How education drives demography and knowledge informs projections. In: Lutz W, Butz WP, KC S, editors. World Population and Human Capital in the 21st Century [Internet]. Oxford: Oxford University Press; 2014. p. 14–38. Available from: http://ukcatalogue.oup.com/product/9780198703167.do

15. Lutz W, KC S. Global human capital: Integrating education and population. Science. 2011;333(6042):587–92.

16. Lutz W, Reiter C, Özdemir C, Yildiz D, Guimaraes R, Goujon A. Skills-adjusted human capital shows rising global gap. Proc Natl Acad Sci. 2021 Feb 16;118(7):e2015826118.

17. Abel GJ, Barakat B, KC S, Lutz W. Meeting the Sustainable Development Goals leads to lower world population growth. Proc Natl Acad Sci. 2016 Nov 29;113(50):14294–9.

18. Asch SE. Studies of independence and conformity: I. A minority of one against a unanimous majority. Psychol Monogr Gen Appl. 1956;70:1–70.

19. Cialdini RB, Goldstein NJ. Social influence: Compliance and conformity. Annu Rev Psychol. 2004;55:591–621.

20. Behrman JR, Kohler HP, Watkins SC. Social networks and changes in contraceptive use over time: Evidence from a longitudinal study in rural Kenya. Demography [Internet]. 2002 Nov 1 [cited 2023 May 30];39(4):713–38. Available from: https://doi.org/10.1353/dem.2002.0033

21. Valente TW. Social network thresholds in the diffusion of innovations. Soc Netw [Internet]. 1996 Jan 1 [cited 2023 May 30];18(1):69–89. Available from: https://www.sciencedirect.com/science/article/pii/0378873395002561

22. Valente TW, Watkins SC, Jato MN, Van Der Straten A, Tsitsol LPM. Social network associations with contraceptive use among Cameroonian women in voluntary associations. Soc Sci Med [Internet]. 1997 Sep 1 [cited 2023 May 30];45(5):677–87. Available from: https://www.sciencedirect.com/science/article/pii/S0277953696003851

23. Bernardi L. Channels of Social Influence on Reproduction. Popul Res Policy Rev [Internet]. 2003 [cited 2023 Jun 20];22(5/6):527–55. Available from: https://www.jstor.org/stable/40230839

24. Bloom DE, Canning DJ, Gunther I, Linnemayr S. Social interactions and fertility in developing Countries. 2008 [cited 2023 May 30]; Available from: https://dash.harvard.edu/handle/1/27022908

25. Bongaarts J, Watkins SC. Social Interactions and Contemporary Fertility Transitions. Popul Dev Rev [Internet]. 1996 [cited 2023 May 30];22(4):639–82. Available from: https://www.jstor.org/stable/2137804

26. Casterline JB, Population NRC (US) C on. Diffusion processes and fertility transition: Introduction. In: Diffusion processes and fertility transition: Selected perspectives. National Academies Press (US); 2001.

27. Dasgupta P. An inquiry into well-being and destitution [Internet]. Clarendon Press; 1993 [cited 2023 Oct 23]. Available from: https://books.google.com/books?hl=en&lr=&id=jIbxDwAAQBAJ&oi=fnd&pg=PR13&dq=An+Inquiry+into+Well-Being+and+Destitution&ots=43kNmgr7V4&sig=vHwpzquda15Ev0bNZIMVzldXHKQ

28. Thornton A, Dorius SF, Swindle J. Developmental idealism: The cultural foundations of world development programs. Sociol Dev. 2015;1(2):277–320.

29. Bongaarts J, Watkins SC. Social Interactions and Contemporary Fertility Transitions. Popul Dev Rev [Internet]. 1996 [cited 2023 Jun 19];22(4):639–82. Available from: https://www.jstor.org/stable/2137804

30. Becker SO, Cinnirella F, Woessmann L. Does women's education affect fertility? Evidence from pre-demographic transition Prussia. Eur Rev Econ Hist. 2013;17(1):24–44.

31. Lutz W. Education empowers women to reach their personal fertility target, regardless of what the target is. Vienna Yearb Popul Res. 2017;15:27–31.

32. Martin TC, Juarez F. The impact of women's education on fertility in Latin America: Searching for explanations. Int Fam Plan Perspect. 1995 Jun;21(2):52–80.

33. Birdsall N, Chester LA. Contraception and the Status of Women: What is the Link? Fam Plann Perspect. 1987;19(1):14–8.

34. Kebede E. The Relative Importance of Female Education on Fertility Desires in Sub-Saharan Africa: A Multi-Level Analysis [Internet]. Vienna, Austria: Vienna Institute of Demography; 2019. (VID Working Papers). Report No.: 09/2019. Available from: http://pure.iiasa.ac.at/id/eprint/16245/

35. Kim J. Female education and its impact on fertility. IZA World Labor [Internet]. 2023 [cited 2023 Oct 16]; Available from: https://wol.iza.org/articles/female-education-and-its-impact-on-fertility/long

36. Yildiz D, Brzozowska Z, Durowaa-Boateng A. A flexible model to reconstruct education-specific fertility rates: Sub-Saharan Africa case [Internet]. Vienna Institute of Demography Working Papers; 2023 [cited 2023 Oct 23]. Available from: https://www.econstor.eu/handle/10419/278613

37. Riahi K. The RCP/SSP Framework [Internet]. Arctic Scenarios Workshop; 2014 May 19; IIASA, Austria. Available from: https://iiasa.ac.at/web/home/about/events/6.Riahi_SSP_ArcticWS_May2014.pdf

38. Riahi K, Van Vuuren DP, Kriegler E, Edmonds J, O'neill BC, Fujimori S, et al. The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. Glob Environ Change. 2017;42:153–68.

39. Lutz W. Distributional aspects of human fertility: A global comparative study. London, UK: Academic Press; 1989.

40. Bongaarts J. The causes of stalling fertility transitions. Stud Fam Plann. 2006 Mar;37(1):1–16.

41. Kebede E, Goujon A, Lutz W. Stalls in Africa's fertility decline partly result from disruptions in female education. Proc Natl Acad Sci. 2019;116(8):2891–6.

42. Schoumaker B. Stalls in fertility transitions in sub-Saharan Africa: Real or spurious? [Internet]. Département des sciences de la population et du développement, Université catholique de Louvain; 2009. Report No.: 30. Available from: http://www.uclouvain.be/cps/ucl/doc/demo/documents/DT_SPED_30_corrige.pdf

43. Schoumaker B. Stalls in Fertility Transitions in sub-Saharan Africa: Revisiting the Evidence. Stud Fam Plann. 2019 Sep;50(3):257–78.

44. Shapiro D, Gebreselassie T. Fertility transition in sub-Saharan Africa: Falling and stalling. Afr Popul Stud. 2008;23:3–23.

Figure Legends

Figure 1: Mean Years of Schooling for Women in a stratum vs. Predicted Average Number of Children per Woman, Cross-Classified by Women's Educational Attainment

Figure 2: Mean Years of Schooling for Women in a Country vs. Predicted Average Number of Children per Woman, Cross-Classified by Women's Educational Attainment

Figure 3: Percentage changes in TFR per unit change in MYS, 32 African countries 1980-85 to 2010-15

Figure 4: scenario forecasts for Kenya

Africa’s Fertility Decline is Partly Driven by Diffusion Processes among Education Groups

Supplementary Information

This supplementary information on “Africa’s fertility decline is partly driven by diffusion processes among education groups” provides 1) The detailed description of method used in the main paper 2) Sensitivity analysis conducted to confirm the diffusion effect in fertility and 3) Fertility projection using diffusion model for all education in selected countries.

Data and Methods

In this study we analyze 1.03 ever married women’s data from 138 Demographic and Health Surveys (DHS) conducted in 39 Sub-Saharan African countries between 1986 and 2022. The table below shows the included countries and survey year of each DHS data set.

Table S1: List of country and survey year from DHS

Country	Survey Years					
Angola	2015					
Benin	1996	2001	2006	2012	2017	
Burkina Faso	1993	1999	2003	2010		
Burundi	1987	2010	2016			
Cameroon	1991	1998	2004	2011	2018	
Central African Republic	1994					
Chad	1997	2004	2014			
Comoros	1996	2012				
Congo	2005	2011				
Congo Democratic Republic	2007	2013				
Cote d'Ivoire	1994	1998	2012			
Eswatini	2006					
Ethiopia	2000	2005	2011	2016	2019	
Gabon	2000	2012	2019			
Gambia	2013	2019				
Ghana	1988	1993	1998	2003	2008	2014
Guinea	1999	2005	2012	2018		
Kenya	1989	1993	1998	2003	2008	2014	2022
Lesotho	2004	2009	2014			
Liberia	1986	2007	2013	2019		
Madagascar	1992	1997	2004	2008	2021	
Malawi	1992	2000	2004	2010	2015	
Mali	1987	1996	2001	2006	2012	2018
Mauritania	2020					
Mozambique	1997	2003	2011			
Namibia	1992	2000	2006	2013		

Country	Survey Years											
Niger	1992	1998	2006	2012								
Nigeria	1990	2003	2008	2013	2018							
Rwanda	1992	2000	2005	2008	2010	2015	2019					
Sao Tome and Principe	2008											
Senegal	1986	1993	1997	2005	2010	2012	2014	2015	2016	2017	2018	2019
Sierra Leone	2008	2013	2019									
South Africa	1998	2016										
Sudan	1990											
Tanzania	1992	1996	1999	2004	2010	2015						
Togo	1988	1998	2013									
Uganda	1988	1995	2000	2006	2011	2016						
Zambia	1992	1996	2002	2007	2013	2018						

Survey questions asked in the DHS to measure ideal and completed fertility

This study used survey data from the DHS,including country specific geographical units. These units, known as clusters and strata, vary across countries as well as vary across surveys for the same country.
The education variables, highest educational attainment, of women is constructed based on the following two questions:

I. Have you ever attended school?

If the answer is no, the response is categorized as "No education" in the survey data. If yes, the respondent is asked the following question:

II. What is the highest level of school you attended: primary, secondary, or higher?

Based on the answers to questions I and II, a new variable, "educational attainment," is created in the DHS data set and categorized into "no education," "primary," "secondary," and "higher" education.These educational categories are based on country specific educational system.

To calculate the mean years of schooling for women in a cluster/stratum, another educational variable is constructed using the following questions in the DHS data:

III. What is the highest level of school you attended: primary, secondary, or higher?
IV. What is the highest (grade/form/year) you completed at that level?

Based on the responses to questions III and IV, the total number of years spent in school is calculated in DHS datasets. Then we calculated mean years of schooling by averaging these total years spent in school.

The completed fertility in our study is the total number of live children ever born to women of age 40 to 49. This information in DHS is collected by asking women the four questions as follows:

V. How many sons live with you? And how many daughters live with you?

VI. How many sons are alive but do not live with you? And how many daughters are alive but do not live with you?

VII. Have you ever given birth to a boy or girl who was born alive but later died?

VIII. If yes to question number VII. How many boys have died? And how many girls have died? If no to question number III, put zero

Using these four question DHS calculated the new variables of total number of children ever born to women by adding the number provided by women in questions V, VI and VII.

The ideal fertility used from the DHS survey is the number of children women idealized to have regardless of how many they have or can have. Information about the ideal number of children is collected by asking women who already have children the following questions:

IX. If you could go back to the time, you did not have any children and could choose exactly the number of children to have in your whole life, how many would that be?

For those who do not have living children, the question is phrased a little differently:

X. If you could choose exactly the number of children to have in your whole life, how many would that be?

1. Assessing the role of diffusion in the fertility decline

In order to examine the relevance of a diffusion process in fertility decline- from highly educated and low-fertility women to less educated and high-fertility women residing in the same area, we fit the following model:

$log(FS_{i,s}) = \beta0 + \beta01 + \beta2MYS_s + \beta3EDUC_{i,s} * MYS_s + U0_S + V_i$--------------(eq.S.1)

It is a mixed-effect Poisson regression model with individual women nested within the stratum. The outcome variables $FS_{i,s}$ represent the family size (ideal or actual) of women residing in the stratum. For a model with ideal family size as an outcome variable, we use data from sample women of reproductive age (15-49), and for the related model with a total number of live births as an outcome, only women at the end of reproductive age (40-49) were considered. The explanatory variable $EDUC_{i,s}$ represents women's educational attainment as a categorical variable: no formal education, primary education, Secondary education, and higher education. The key predictor MYS_s stands for the mean years of schooling in a stratum. The interaction term captures how the effect of stratum-level mean years of schooling changes based on individual's educational attainment. The parameter $U0_s$ is random intercept for stratum s accounts variability between strata. Whereas V_i is random effect for individual i capturing variability with-in stratum. The results reported in Figure 1were predicted from the above model as the expected family size for individual i with education $EDUC$ for different levels of MYS.

Table S2 presents the incident rate ratios (IRR) along with lower limits (LL) and upper limits (UL) derived from the model. The estimates indicate that women with secondary and higher education tend to idealize family sizes 0.78 and 0.69 times smaller, respectively, compared to uneducated women.

Similarly, in terms of behavior, these secondary and higher educated women also exhibit 0.84 and 0.62 times fewer children over their lifetime than their uneducated counterparts. Moreover, within the same group of women, completed fertility decreases by 0.98 and 0.99 times for each unit change in the mean years of schooling (MYS) of the strata in which they reside.

Table S2: Incident rate ratio for ideal and actual family size from model of eq S.1

Variables	Labels	IRR (LL-UL)	
		Ideal family size	Completed family size
	Intercept	6.684***(6.64-6.729)	6.858***(6.821-6.896)
Education (ref="No education")	Primary Education	0.899***(0.895-0.902)	0.995(0.988-1.003)
	Secondary Education	0.785***(0.78-0.79)	0.845***(0.833-0.856)
	Higher Education	0.699***(0.686-0.712)	0.626***(0.605-0.648)
Community education	MYS community	0.96***(0.958-0.961)	0.977***(0.975-0.979)
Interaction effect	Primary: MYS community	0.999***(0.997-1)	0.991***(0.989-0.993)
	Secondary: MYS community	0.998**(0.997-1)	0.987***(0.984-0.989)
	Higher: MYS community	1.002(0.999-1.005)	0.995**(0.99-1)

*** p<0.001; ** p<0.05; * p< 0.1

2. Estimating the education specific 'diffusion rate':

In an effort to translate the examined diffusion effects into the national level fertility forecasting, we computed the marginal effect of changes in national-level mean years of schooling between 1980/85 and 2010/15 to the change in TFR over the same period. We chose this observation window based on the availability of consistent time series data on education-specific total fertility rates, which began in 1980. We estimated the education-specific "diffusion rates" as the percentage change in TFR for a unit change in MYS as follow:

$$Diffrate_{c,e(1980/85-2010/15)} = \left[\frac{TFRc,_{e(1980/85)-TFRc,_{e(2010/15)}}}{TFR_{c,e(1980/85)}}\right] \cdot \frac{1}{MYS_{c(2010/15)-MYS_{c(1980/85)}}}$$ ------------------

(eq.S.2)

Where : - $Diffrate_{c,e(1980/85-2010/15)}$ is the marginal effect of overall improvement in MYS in counry c on the change in TFR of women of eduation group e between 1980/85 and 2010/15.

- $\left[\frac{TFR_{e(1980/85)-TFR_{e(2010/15)}}}{TFR_{e(1980/85)}}\right]$ is the percentage change in TFR for women of education group e over the period 1980/85-2010/15
- $MYS_{c(2010/15)-MYS_{e(1980/85)}}$ is the overall change in MYS counry c between 1980/85 and 2010/15

In the later step, we averaged the % change in education-specific TFR per unit change in MYS across all countries for each of the four education levels, which we named the "education-specific diffusion rate". The education-specific diffusion rate is then used to make the education-specific TFR projection described below.

3. Incorporating the diffusion process in the national level fertility forecasting

To incorporate the diffusion in the national-level fertility forecasting model, we apply the above estimated "education specific diffusion rates" to the projected mean years of schooling from 2010/2015 to 2045/2050 by the WIC human capital projections under the so-called shared-socio economic pathways scenarios (SSP1, SSP2, SSP3) as follow:

$TFR_{c,sspi\,(t+5)} = TFR_{c,sspi\,(t)} + \big[TFR_{c,(t)} * Diffrate_{e\,(1980/85-2010/15)} * \big(MYS_{c,sspi\,(t+5)} - MYS_{c,sspi\,(t)}\big)\big]$------------ (eq.S.3)

Where: $t\ is\ \ the\ 5\ years\ projection\ interval\ , 2010-15, 2015-20, \dots\dots..2045-50$

: $TFR_{c,e(t)}\ is\ the$ education specific TFR for country c at the base period t under the shared socio-economic pathway (SSP) scenario i(=1,2,3).

: $TFR_{c(t+5)}$ is the estiamted education specific TFR for country c in the subsquent projection interval t+5, under the shared socio-economic pathway (SSP) scenario i(=1,2,3).

: $Diffrate_{\ e(1980/85-2010/15)}$ is the percentage change in education specific TFR for a unit change in national level mean years of schooling between 1980/85 and 2010/15, as described in (eq.S.2)

: $MYS_{c,sspi\,(t+5)} - MYS_{c,sspi\,(t)}$ is the change in estiamtednational level MYS for country c under the shared socio-economic pathway (SSP) scenario i(=1,2,3) in the subsequent projection interval $[t, t+5]$

Overall TFR (not education-specific) for each projection interval in the projection period (2010-2050) was computed using a similar strategy, but the diffusion rates averaged across education groups and countries.

Sensitivity Analysis

To test the diffusion effect in fertility intention and behavior we performed three different sensitivity analysis. In figure S1 and Figure S2 we test the effect on individual education and stratum MYS on ideal and completed fertility using model S.1 but we added rural and urban place of residence as additional predictor variable in the model. These aimed to explore whether this decline was a result of diffusion or influenced by other factors, such as urbanization and socio-economic developments over time. Our analyses consistently revealed similar patterns, even when accounting for rural and urban regions. Figure S1 and Figure S2 illustrate the ideal and actual fertility among women with all four levels of education, separately for rural and urban regions. This pattern closely resembles the one presented in Figure 1 of the main paper, with a slightly higher actual fertility among less educated women in rural areas and slightly lower fertility levels in urban areas as expected.

Figure S1: DHS, ideal Family size (left) and completed fertility (right) by education groups and MYS in Rural Stratum by including data collected between 1986 and 2022

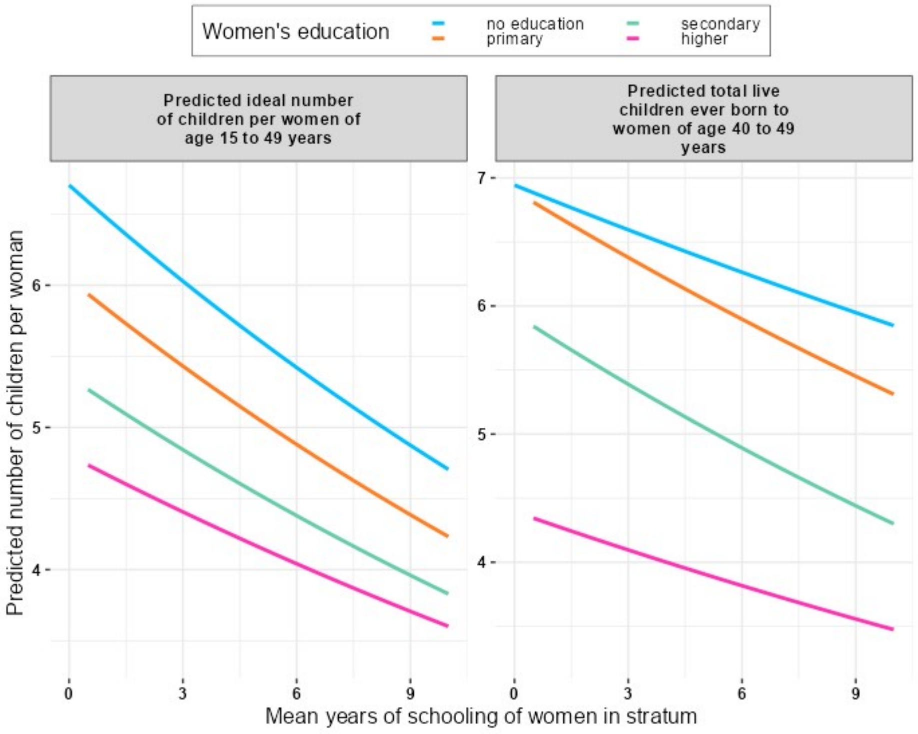
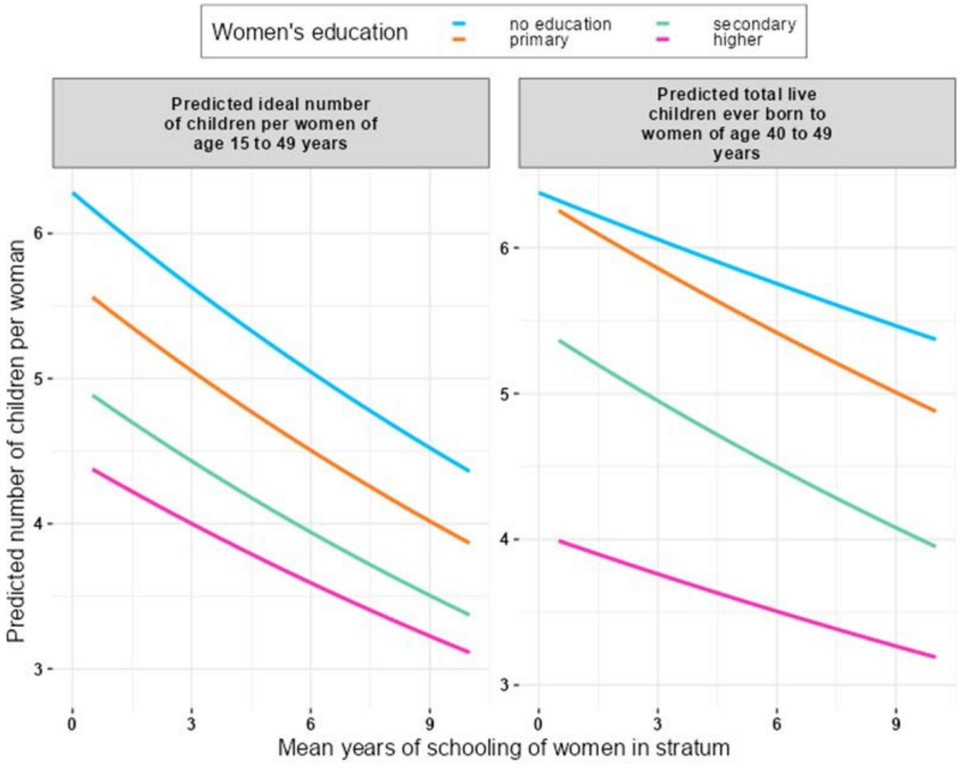


Figure S2: DHS, ideal Family size (left) and completed fertility (right) by education groups and MYS in Urban Stratum by including data collected between 1986 and 2022



We further tested the results in Figure 1 of the main paper by including only the most recent data from the Demographic and Health Surveys (DHS) for each country. The goal was to investigate whether the observed pattern, attributed to diffusion, might be influenced by changing socio-economic factors such as increased access to contraception or shifts in the economy over time. To address this, we narrowed our analysis to include only the latest available data collected after 2010 for each country, totaling 34 countries. Figure S3, presented below, illustrates fertility trends based on women's education and mean years of schooling (MYS) within specific strata using latest available DHS data. Once again, a consistent gradient and pattern in fertility emerged, affirming that the declining fertility associated with women's education and the additional decline linked to increasing MYS within specific strata are indeed the result of the diffusion effect.

Figure S3 DHS, ideal Family size (left) and completed fertility (right) by education groups and MYS in Stratum, used only latest survey data from 2010 to 2022.

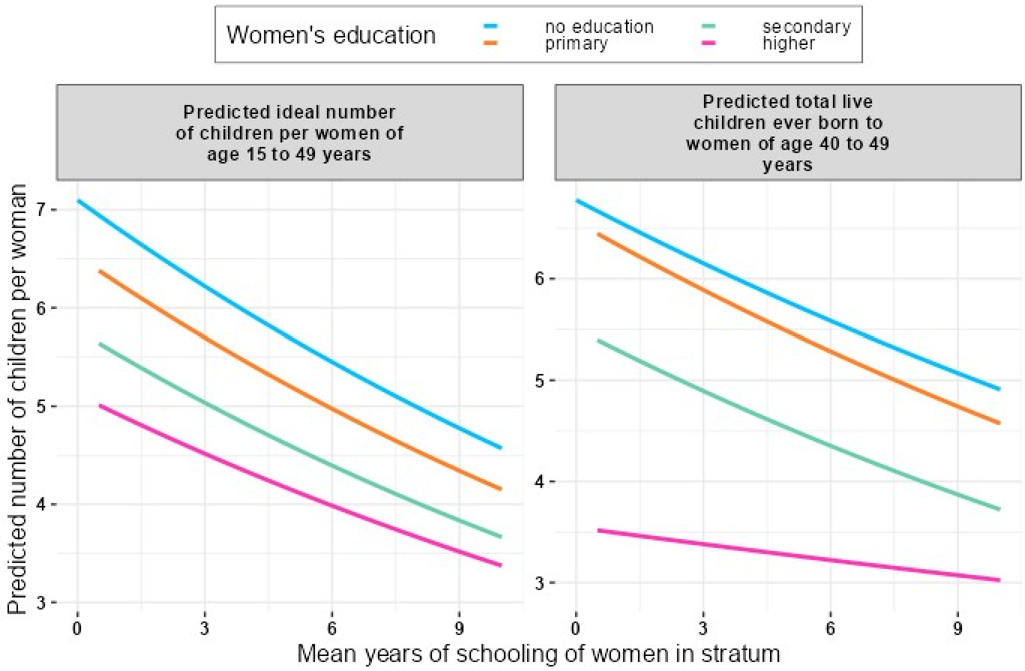
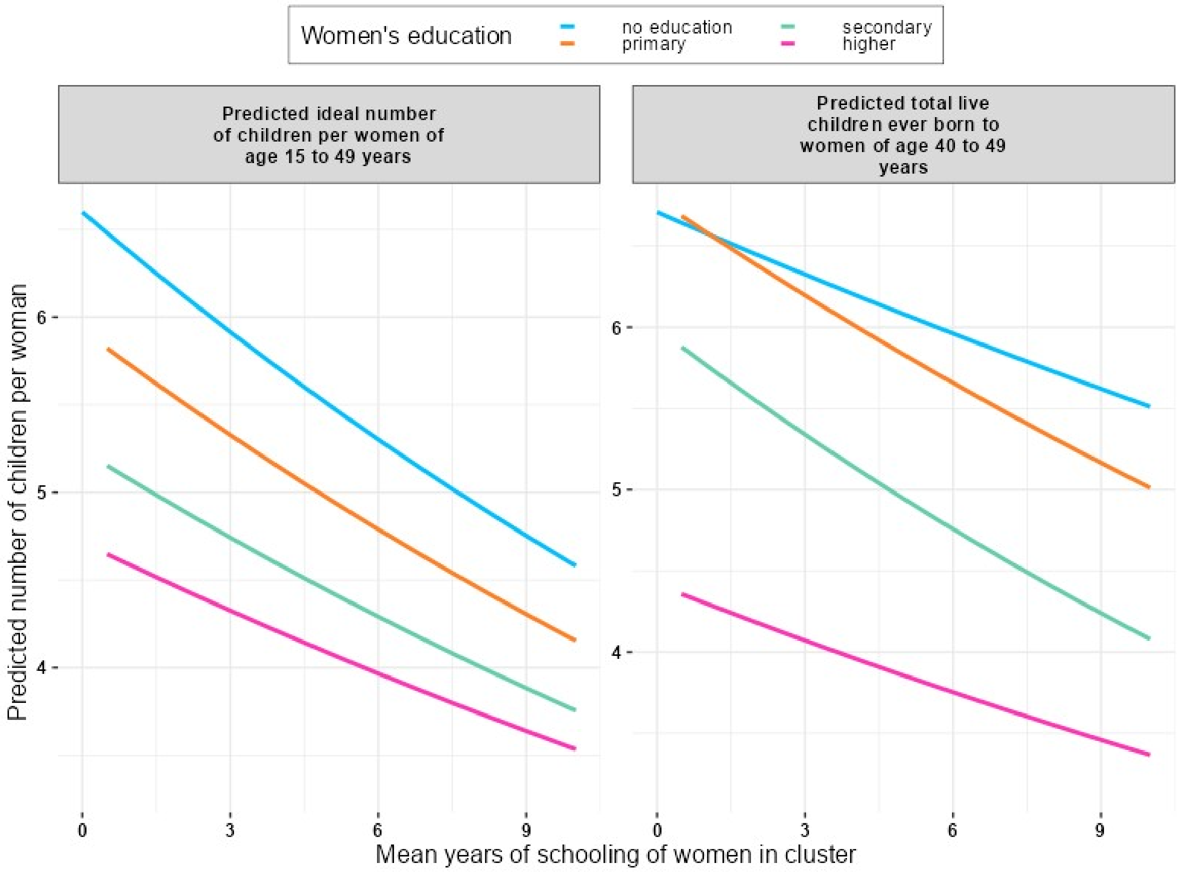


Figure S4 displays a diffusion pattern closely resembling the one illustrated in Figure 1 of the main paper. However, it is crucial to note a distinction: the diffusion pattern in Figure S4 is observed at the cluster level, the smallest geographic unit in the DHS, as opposed to the stratum level in Figure 1 of the main paper. Despite this difference in geographic units, the overall trends remain remarkably similar. Both patterns reveal a gradual decline in both ideal and actual fertility with increasing mean years of schooling (MYS) at the community level (stratum or cluster). Notably, at the cluster level, the decline in fertility is more pronounced, indicating rapid diffusion of smaller family concepts and behavior within these smaller geographic clusters.

Figure S4: DHS, ideal Family size (left) and completed fertility (right) by education groups and MYS in Cluster, used survey data from 1986 to 2022.



Fertility forecasting for all education group in Kenya and Nigeria

Figure S5 and S6 presents the past and projected trends in overall and education-specific Total Fertility Rates (TFR) following the SSP scenarios for the case of Kenya and Nigeria respectively. The red line gives the UN estimates and projections of the overall TFR. The purple line (Diff_tot) gives the projections resulting from applying the estimated average diffusion rate to the 2010-15 empirical overall TFR (without differentiating by level of education) and the black line (Diff-ed) shows the projections resulting from applying the average diffusion effect to education-specific TFRs (for four education levels) and aggregating them to overall TFRs also reflecting the changing proportions of different education groups (composition effect) according to the SSP2 (medium) education expansion scenario. The Diff_tot, which does not include the education composition and only includes average diffusion rate 12% change in overall TFR (without education) per unit change in MYS (according to SSP2 scenario for projection period) in country showed lower TFR than the UN TFR projection and Diff_ed projection. In the case of education specific TFR, the education specific diffusion rate 9.3%, 11.3%, 12.4%, 14.3% change in TFR per unit change in MYS is used for no education, primary education, secondary education and higher education respectively.

Figure S5: scenario forecasts for Kenya, all education

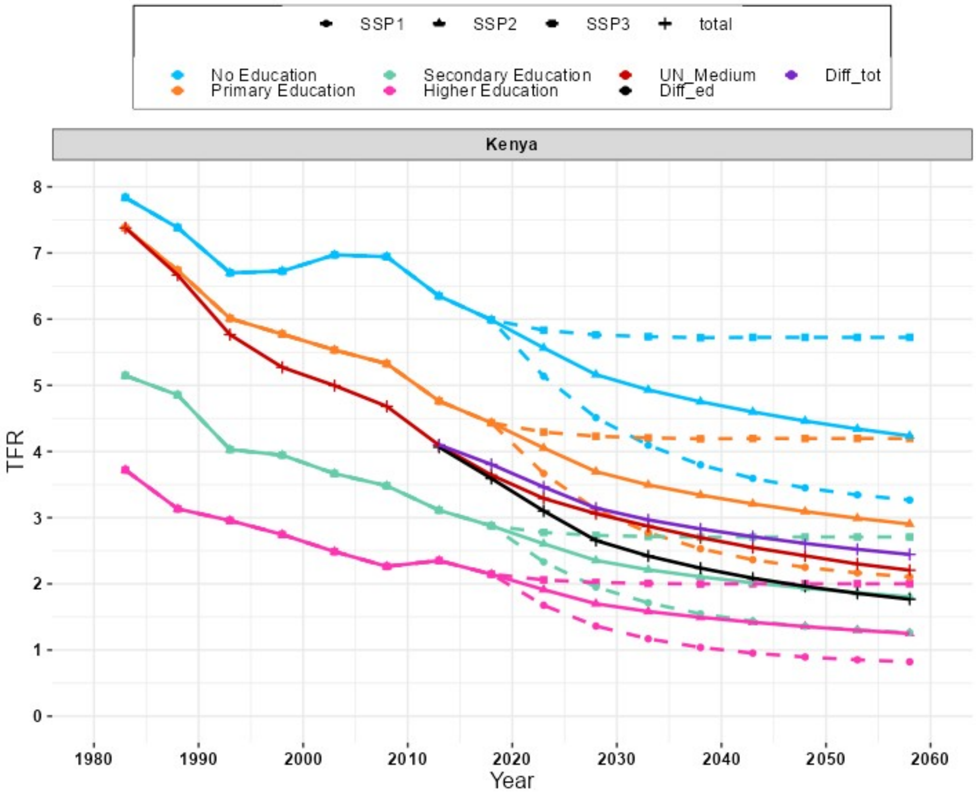
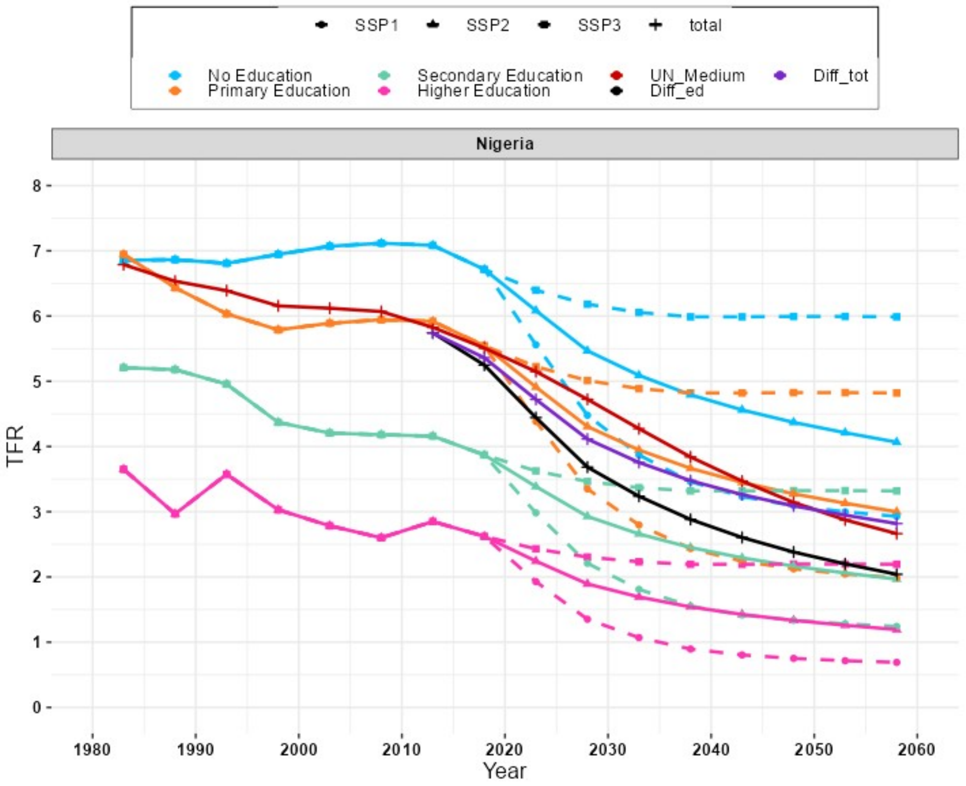


Figure S6: scenario forecasts for Nigeria, all education



2.3 Examining the role of female education on son preference among Nepalese women

Author: Saroja Adhikari (sarojaadhikari2@gmail.com / adhikaris@iiasa.ac.at)

This article was originally published by the International Institute for Applied Systems Analysis in 20 April 2023 and also submitted to Asian population studies journal on 13 June 2023, which is currently under peer review, and is reprinted here with permission.

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

Examining the role of female education on son preference among Nepalese women

Saroja Adhikari (adhikaris@iiasa.ac.at)

WP-23-010

Approved by:

Anne Goujon
Program: Population and Just Societies
Date: 21 November 2023

Table of contents

Abstract 3
About the authors 4
Acknowledgments 4

Introduction 5
Research Question 10
Data and Methods 12
Results 16
Conclusions and Outlook 25
References 28
Appendix 32

Appendix A: TFR by education and rural/urban place of residence 32
Appendix B: Countries and survey years used in multilevel analysis 36

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

This paper investigates the impact of female education on son preferences in Nepal. It analyzes changing trends in son preferences in children among Nepalese women from 1996 to 2022 based on data from the Nepal Demographic and Health Surveys (NDHS). Using multivariate and multilevel regression, the study explores the roles of both individual and contextual education in reducing son preference. In addition to individual female education, a novel contribution of this research is the identification of a compositional effect of education on son preference. Furthermore, the study investigates the relationship between women's son preferences and their partner's education to check whether the latter also influences the gender preference of women in children. The positive association between the compositional effect of higher education and lower son preference suggests the need for policymakers to prioritize female education as one of the key investments to reduce son preference. The results highlight the importance of future research on how education's individual and compositional effects influence the sex ratio at birth. This is crucial for making informed decisions about including individual and compositional education effects in population projection models to better project future sex ratio at birth and population structure.

Keywords: *Son preference, Female education, Nepal, Sex ratio at birth*

About the authors

Saroja Adhikari is a researcher in the Population and Just Societies Program at the International Institute for Applied Systems Analysis (IIASA) (Contact: adhikaris@iiasa.ac.at)

Acknowledgments

The author gratefully acknowledges funding from the European Research Council for the research project ‘The Demography of Sustainable Human Wellbeing’ (EmpoweredLifeYears/grant agreement No 741105).

Introduction

Son preference is a long-standing aspect of Nepalese society; however, it becomes more evident as fertility decreases. In Nepal, the average number of children born per woman dropped from 4.6 in 1996 to 2.1 in 2022. In the same period, the Sex Ratio at Birth (SRB) significantly increased from around 106 to 119.1 male births per 100 female births (Ministry of Health and Population et al., 2022). Commonly, the SRB would lie around 103 to 107 male per 100 female birth. The male-biased skewed SRB (MBSRB), characterized by a SRB tilted towards more male births than naturally expected, is a topic of interest in many Asian countries because of the short and long-term implications on marriage patterns, fertility, population structure, inequality, and violence (Diamond-Smith & Rudolph, 2018; Feldman & Li, 2012; Guilmoto, 2012). While a large body of literature examines MBSRB and son preference in countries such as India, China, and Pakistan, research on son preference and its mitigating factors in Nepal is limited (Leone et al., 2003; Rai et al., 2014).

When Nepal transitioned from high fertility to low fertility, MBSRB became more prevalent. Despite the illegality of sex-selective abortion in Nepal, increasing MBSRB indicates a consistent rising trend in the abortion of female fetuses. Most couples in Nepal idealize a family with two children, one son and one daughter (Sapkota et al., 2019), however not all can achieve this ideal child composition within their idealized family size. Therefore, when couples do not have a son within their ideal family size, they may end up having more children than idealized because of son preference. On the other hand, couples may also want to achieve their lower idealized number of children but feel compelled to prioritize having a son, leading to pressure to avoid having daughters through sex-selective abortion (Brunson, 2010; Frost et al., 2013; The Kathmandu Post, 2023; Yi et al., 1993).

The MBSRB is a clear indication of gender discrimination, which is linked to various adverse health outcomes for females. Research in South Asian countries, including Nepal, shows that female children with older female siblings are more likely to suffer from malnutrition and stunted growth compared to those with older male siblings (Fledderjohann & Channon, 2022; Mitra, 2014; Raj et al., 2015). Studies from India, Bangladesh, and Pakistan have demonstrated that parents often continue having children until they achieve their desired number of sons, frequently resulting in a lack of resources and care for female children. This disparity leads to higher rates of infant and child mortality among girls (Arnold et al., 1998; Gupta, 1987). While the absence of male siblings is associated with severe malnutrition and mortality risk for female children in Nepal, there is no definitive evidence supporting a direct relationship between son preference and female child mortality (Fledderjohann & Channon, 2022). Son preference has also been linked to intimate partner violence (IPV) against women in Nepal and India (Deuba et al., 2016; Weitzman, 2020). Having a firstborn daughter or no sons is found to increase the risk and severity of IPV in both countries. Weitzman's (2020) study shows that the severity of IPV due to the absence of sons is highest among women with no formal education.

MBSRB, a consequence of son preference in Nepal, is driven by the cultural and economic importance placed on sons over daughters. Nepalese society values sons for continuing the family lineage, which is important for continuing ancestral worship (Nanda et al., 2012; Sapkota et al., 2019; Acharya, 2019). Ancestral worship, performed by only male child (son or grandson) is considered to bring peace to deceased parents or grandparents; therefore, having a son is important from the parents' perspective even after their death. Besides the collective benefits for parents, having a son is important to increase female autonomy in household decisions. Studies from Pakistan, Nepal, and India (Gopalakrishnan et al., 2023; Gudbrandsen, 2013; Javed et al., 2019) show that having a son increases the woman's decision-making power and involvement within the decision-making of in-law family. Another factor of son preference in Nepal is the expectation of sons to provide physical and financial support to parents in their old age. In Nepal, parents usually co-reside with their son and his family, where the daughter-in-law takes on responsibilities for caregiving for in-laws and household chores. Since the government lacks significant old-age support and benefits, the son and his family become a primary source of physical, financial and emotional support for parents as opposed to daughters who traditionally move to their husbands' families after marriage. Therefore, having a son is considered to be important in Nepal to secure all forms of support at an older age. Research across various countries also shows that son preference is prevalent in countries where parents commonly reside with their married son (Ebenstein, 2021; Ebenstein & Leung, 2010).

Female education has been one of the major factors that is positively associated with socio-economic development as well as female autonomy. Various studies from developing countries, including Nepal, have shown a consistent positive relationship between female education and higher female autonomy regarding household decision-making, health care decisions and reproductive decisions (D. R. Acharya et al., 2010; Nigatu et al., 2014; Sheikh & Loney, 2018). Education is considered to empower women to realize their fertility intention (Lutz, 2017) and negotiate within their families and communities (Jose & Younas, 2023; Kien & My, 2021; Medel-Anonuevo, 1995; Stromquist, 2015). Educated women are also more likely to access paid job opportunities (Heath & Jayachandran, 2018; Lincove, 2008), enabling them to secure their future financially without relying on their husbands and sons. Educated women can also make financial and non-financial decisions (Kien & My, 2021). Education can empower women to challenge the existing gender norms through knowledge and skills, such as finance and rational thinking capacity. Therefore, female education may help to reduce son preference in countries where the importance of having a son is generally a social norm. Some studies in developing countries have already established a positive association between female education and reduced son preference (Nguyen & Le, 2022; Raza, 2023). However, the measurement of son preference in those studies is controversial and considered to have serious flaws (Jayachandran, 2017). This study will therefore investigate the relationship between female education and son preference in Nepal by using information regarding whether women want additional children once they meet their idealized number of children based on the sex composition of their previously born children.

Besides the individual advantage of female education on rational choices and decision-making regarding fertility and gender norms, there is also an additional compositional effect. As human beings are inherently influenced by the behaviour and choices of those around them, the desire to conform and gain acceptance from their social circles, including friends, family, and neighbours in proximity, is a powerful motivator to make decisions (Asch, 1956). The collective behaviour in society forms societal norms that guide individuals in their decision-making and behaviour (Cialdini & Goldstein, 2004). In the context of Nepal, where son preference is a prevalent social norm, residing in a community with norms preferring sons may lead individual women to share the same preference for sons regardless of their education.

Research statement and questions

Previous literature on son preference in Nepal showed the greater values associated with sons regarding the financial and physical support to parents and the cultural norms regarding the continuation of family lineage. Even though female education is associated with greater financial stability through paid jobs and greater autonomy to make decisions regarding fertility, as discussed above, there appears to be a gap in research addressing the direct impact of female education on son preference in Nepal over the last two decades. Education helps individuals see the world from a different perspective and evaluate their choices and decisions with different rationality than uneducated people do (Lutz, 2022). Therefore, there can be differences in the son preference between women of different education.

The enrollment of Nepalese women in higher education has significantly increased, rising from 23% in 1992 to 52% in 2018. During the same period, female participation in the labour force also increased from 25.3% to 37.8% (D. R. Acharya, 2021). This shift in female education and labour force participation has the potential to reshape women's perspectives on gender norms. In light of these changes, this study aims to investigate the evolving trend of son preference in childbirth, considering women from various educational backgrounds and diverse societal contexts over the past 25 years. The research delves into son preference in childbirth trends by assessing whether women desire additional children after achieving their idealized number of children.

Previous studies in Nepal primarily focused on son preference in relation to the ideal sex composition of the ideal number of children. As the majority of women prefer to have two children (57% in the sample of this study), one son and one daughter, son preference among these women was often overlooked. Since not all women are able to have both a son and a daughter in their first two births, some may have two sons or two daughters instead. Hence, this study investigates whether women desire to have additional children after reaching their ideal number of children, where they have only sons, only daughters, or a mix of both. This analysis assumes that the absence of a son may influence women to have more children than idealized if a son preference still exists. Based on this objective to investigate the desire for additional children in the presence and absence of a son, this paper assessed the following two research questions:

1. How does female education impact son preference, and how does this relationship change over time?
2. Does female education have a compositional effect on son preference in addition to the individual education level?

By investigating son preference in birth within communities at various education levels, the study provides insights into how son preferences may evolve as education continues to expand in the future. The outcomes of this study have practical implications for policy development, particularly in addressing the pressing issue of sex-selective abortions through female education. Furthermore, the findings can be used to better project the SRB in Nepal for future population projection, especially during social transitions from lower to higher levels of female education.

Hypothesis

Based on the established positive relationship between female education, female employment, and female autonomy, I propose the following hypotheses:

1. Women with higher levels of education can support themselves financially and have bargaining power within the family and society to reach their fertility preference. Therefore, highly educated women do not feel compelled to have sons, and son preference in birth decreases with increased female education.

2. Son preference in birth is a prevalent social norm in Nepal. Women feel compelled to have sons because of social pressure. However, when women live in a community where their peers have higher levels of education, the prevailing social norms in that community may lean more towards a reduced emphasis on son preference, aligning with the attitudes expected to see in highly educated women. Women may encounter less societal pressure to have a son in such cases. Therefore, an increase in higher educated women in a community decreases son preference.

Data and method

The Nepal Demographic Health Survey (NDHS) was conducted at six different time points in Nepal: 1996, 2001, 2006, 2011, 2016, and 2022, involving 53,484 interviews with women of reproductive age 15-49.

Among them, 39,898 (74.6%) ever-married women who had already met their ideal number of children were included in the study. This study includes only ever-married women who have already achieved their ideal number of children, assuming women will stop childbirth once they meet their idealized family size unless they specifically desire children of a certain gender. Based on Arnold, (1997) definition, gender preference in birth is considered to have existed if the probability of wanting additional children within specific parity differs significantly by the gender composition of already-born children. So, if women who had no sons or had only daughters wanted additional children after meeting the idealized family size, they were considered to have a son preference. Using this criterion, we investigate how the gender composition of previously born children impacts the desire for additional children among women with different education levels across various years and in diverse communities.

A multivariate binomial model is used to investigate the son preference among women with different education levels. The dependent variable is the desire to have additional children, categorized into two groups: "wanting or undecided" versus "not wanting". Only 0.9% of the sampled women were undecided about wanting additional children; 53% had no sons, and 22% had no daughters. Therefore, women who wanted more children and those undecided were grouped, assuming the uncertainty might be related to not having children of a specific gender.

The first model examined how the son preference changes over time for women with different educational backgrounds. Women's education is categorized into three groups: "no education", "primary", and "secondary or above". Similarly, the gender composition of previously born children is also categorized into three groups: only sons (no daughters), only daughters (no sons) and both (both son/s and daughter/s).

Secondly, the multilevel binomial regression model is used to estimate the interaction effect of the community's education and the gender composition of previously born children separately for women with different levels of education. Community education is measured by taking the mean years of schooling (MYS) of sampled women in each NDHS stratum. NDHS stratum is the group of multiple NDHS clusters (smallest spatial unit of DHS). Overall data includes 459 communities. The average sample size in each stratum is 355 women, and 75% of the stratum consists of at least 50 sampled women. In multilevel binomial regression model individual women were considered as a first or individual level who are nested within community (second level) and community also nested within survey years. Using multilevel modeling also avoids the effect of changing socio-economic development on son preference over time. NDHS data from 1996 to 2022 are pooled together, with the survey year and community included as a fixed effect (Hazlett & Wainstein, 2022).

A sensitivity analysis is also performed to see whether the husband's education impacts the women's son preference, i.e., to explore whether the son preference among women is because of the pressure put by the husband on his wife.

The multivariate equation for each model is given below:

$y = \beta_0 + \beta_1$ * survey year: gender composition of previously born children + $\beta 2$ * birth parity + e................ (1)

Log (p_{ijk} / (1 - p_{ijk})) = $\beta_0 + \beta_1$ * community MYS_{jk}: gender composition of previously born children_{ijk} + $\beta 2$ * birth parity_{ijk} + $u_{jk}+v_k+e_{ijk}$................ (2)

Where, p_{ijk} is the probability of wanting additional child by an individual woman i living in the community j and surveyed in the year k. community MYS_{jk} is the MYS in community j surveyed in year k. gender composition of born children_{ijk} is the gender composition of children of women i living in community j and surveyed in year k. Birth parity_{ijk} is the total number of children woman i living in community j and surveyed in year k have had. u_{jk} is the fixed effect specific to the j-th community surveyed in year k.
v_k is the fixed effect specific to the kth survey year.
e_{ijk} is the residual error term representing individual-level variability.

Log (p / (1 - p)) = $\beta_0 + \beta_1$ * Partner education: gender composition of born children + $\beta 2$ * Birth parity .... (3)
Where: p represents the probability of wanting to have additional children

β_0 is the intercept term, β_1 and β_2 are the coefficients of respective variables.

All models run separately for each of three education level of women.

Result

Initially, the SRB is computed for women at various parities. The objective is to examine the variation in SRB between firstborn and lastborn children and to determine whether there is a preference for a specific gender in different birth orders. Figure 1 illustrates the SRB for both the first- and lastborn child among 14,746 women who idealized and had two children at the time of the interview (left side of Figure 1). The right side of Figure 1 shows the SRB among 5,669 women who idealized two children but ended up having three. Among the participants, 57% idealized having two children, while almost 24.2% aimed for three children. The inclusion of women who achieved their idealized number of two children on the left side of the figure allows to investigate whether sex selection occurs within the idealized number of children. Conversely, the right side of Figure 1 includes women who had three children, irrespective of their initial idealization of two children. This is based on the assumption that those who originally idealized two children might opt for sex selection at the third birth if they did not have a son within their idealized number of children.

On the left side of Figure 1, the SRB for the firstborn child (depicted by the yellow line) and the SRB for the second-born child, given that the firstborn is a son (shown by the blue line in the figure), exhibit a similar trend. However, there is a notable increase over time when considering the SRB for the second-born child, given that the first child is female (represented by the pink line in the figure). Specifically, the SRB increased from around 150 male births per 100 female births in 1996 and 2000 to a peak of 225 male births per 100 female births in 2016 before experiencing a slight decrease in 2022. However, on the right side of Figure 1, the SRB skews towards more female births for the firstborn (a similar pattern is observed in parity four; see Appendix D). This shift is because most women with daughters as their first child or their first two children opt to have three children to ensure they have at least one son. The SRB of the lastborn child is significantly skewed towards more male births if the first two children are daughters. This MBSRB becomes even more pronounced with increasing birth orders because the majority of women who continue to have more children are those who have not yet had a son and keep giving birth until they have at least one son. Overall, this result supports that despite the illegality of sex-selective abortion, there is a clear sex selection happening in the second and higher birth orders in Nepal to ensure having at least one son.

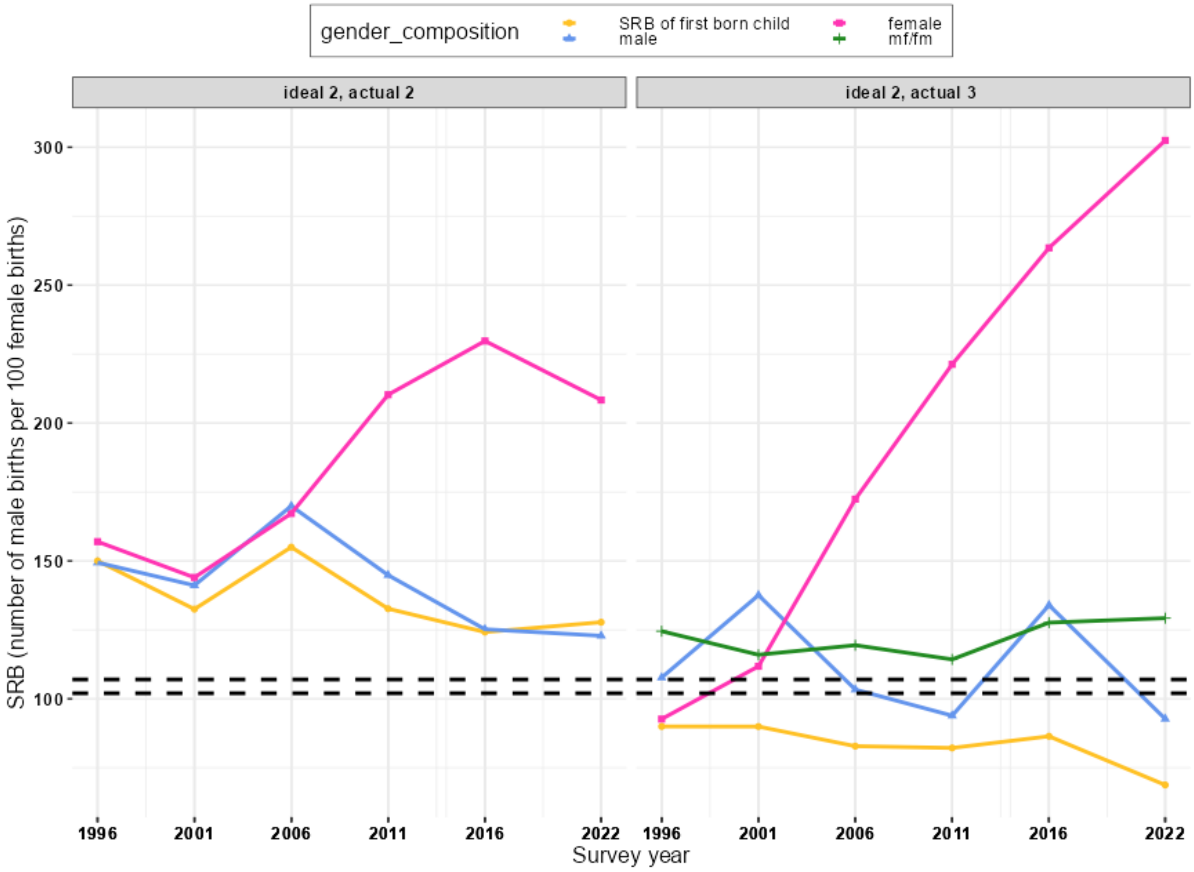


Figure 1: SRB of last-born child by the gender composition of previously born children and SRB of first child [1]among women idealized two children and had two surviving children (left side) and had three surviving children (right side) between 1996 and 2022

Secondly, the study examined how son preference changes over time among women with different educational backgrounds. To do this, I used a Binomial regression model to estimate the probability of wanting another child based on the gender composition of their previously born children in each survey year. This probability is estimated separately for women with three different education levels.

These analyses are limited to women with at least two children and who have achieved their ideal family size. Overall, for women with only daughters (no sons), the desire to have more children after reaching their ideal number of children, which is called son preference in this text, is significantly higher than for those who have only sons (no daughters), indicating son preference. This son preference, however, has changed slightly over the last 25 years. For all women, regardless of their education level, son preference decreased by 20

[1] SRB for the first child is calculated without considering the gender composition of previously born children, given that no children were born prior to the first child.

percentage points, starting from a 50% likelihood to desire additional children in 1996 to a 30% likelihood in 2022. However, this decline is mainly influenced by women with no formal education, for whom the probability decreases from around 60% in 1996 to 30% in 2021. For educated women, primary or secondary and above, the probability of wanting more children decreases slightly from around 40% in 1996 to 25% in 2022. Initially, education had a significant impact, especially between those with some education and those with none. As stated in Hypothesis 1, women with higher levels of education might exhibit reduced son preference due to their capacity for financial security and empowered decision-making stemming from their education. However, this effect of education became less significant over the period. This change from a more significant to less significant educational gradient in son preference over time may be attributed to the effect of social norms. It is plausible that social norms emphasizing the importance of having a son could still contribute to a certain degree of son preference among all women, including educated women. Numerical estimates from the model is provided in Appendix A.

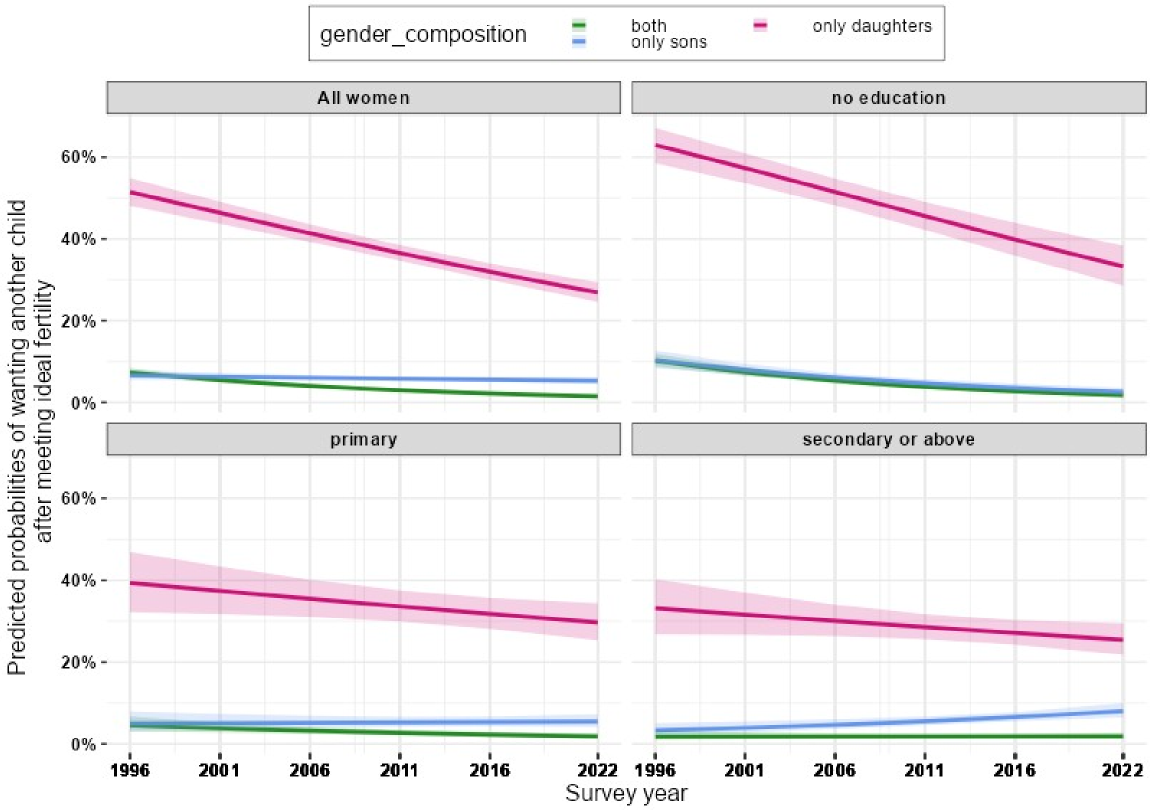


Figure 2: probability of wanting additional child after meeting ideal fertility by survey year and gender composition of previously born children for parity 2, stratified by individual education.

In this study, I further looked into the influence of community education, or the compositional effect of education, on the son preference of women with varying educational backgrounds. To do this, data from all surveys were pooled together. By using a binomial regression model with fixed effects for both community and survey years, the impact of community education on son preference is estimated. The survey year was incorporated as a fixed-effect variable to account for the potential influence of changing socio-economic development over time. Each stratum of each survey was treated as a unit of community, resulting in a total of 459 strata or communities. These communities were characterized by the mean years of schooling of the sampled women.

Figure 3 visually represents the probability of women desiring an additional child with at least two children, based on community education where women reside and the gender composition of their previously born children. This analysis provides insights into how community education levels relate to son preference among women with different educational backgrounds. The finding shows an additional compositional effect of education in reducing son preference. Specifically, when residing in communities with lower MYS, women with no sons tend to have a higher probability of wanting additional children than those living in higher MYS. In the community with the highest MYS (8 years of schooling), the probability of wanting an additional child for women with no sons is only 10% for all education groups. In general, for each unit increase in MYS within a community, the likelihood of wanting additional children among women with only daughters decreases by 12% relative to the initial probability. This reduction is 23% for those with no education, 29% for primary education, and approximately 15% for secondary education or higher. It is worth noting that while gender preference is at its lowest in highly educated communities, daughter preference (blue line in Figure 3) is almost as pronounced as son preference among secondary or above-educated women residing in highly educated communities. This increasing daughter preference is mainly pronounced among women with one child and almost insignificant if they had two or more children (see Appendix B).

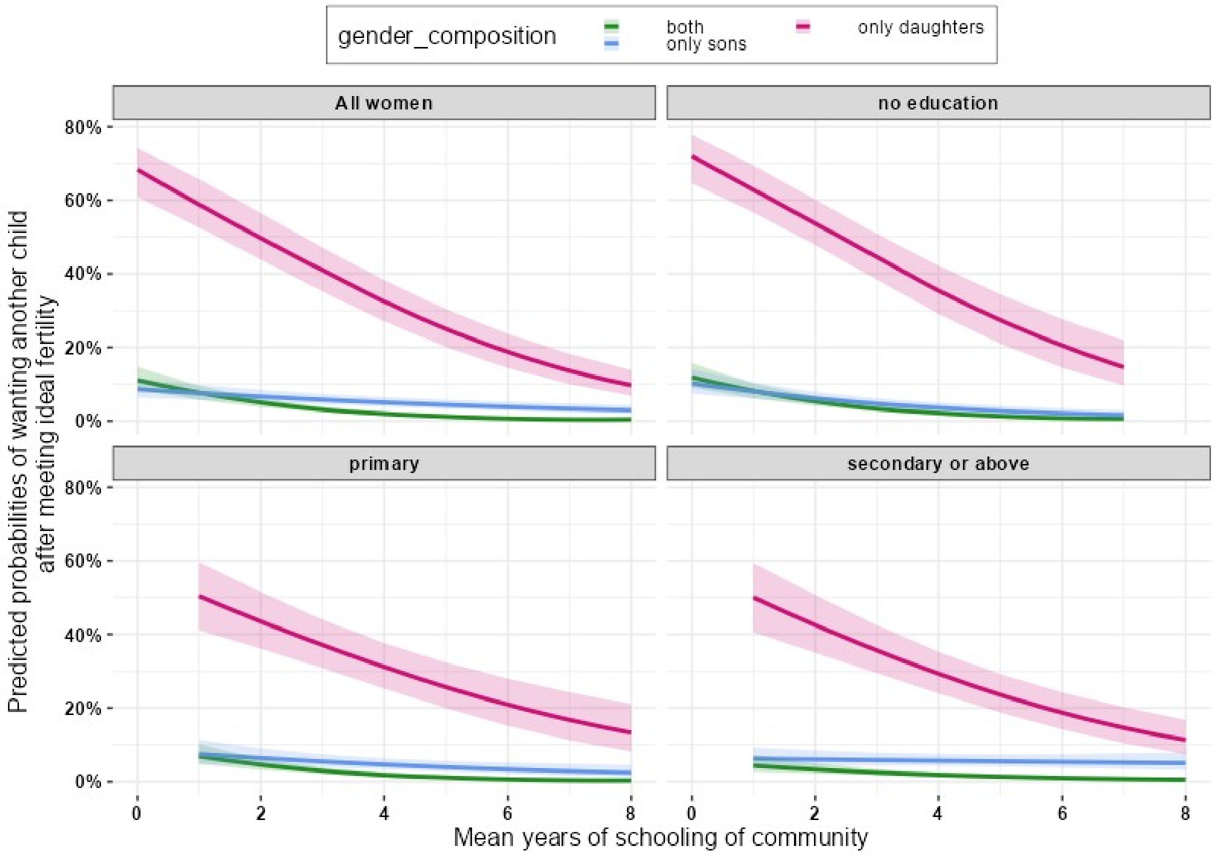


Figure 3: Probability of wanting an additional child after meeting ideal fertility by gender composition of previously born children and community education for parity 2, stratified by individual education

We included the education level of a woman's partner and women's individual education to see if it impacts the son preferences of women. Appendix E visually shows the likelihood of women wanting more children, along with the associated standard errors, based on two education categories: "no education" and "some education" for both women and their partners. In this context, "some education" means that the woman or her partner has had some formal education. The interesting finding is that, overall, a woman's partner's education level does not significantly influence her preference for having sons. This lack of influence could be due to a few reasons. One, there may not be significant differences in educational attainment between women and their partners in the study population. Additionally, shared social values and norms within families and the communities where they both live might play a more prominent role in shaping the son preference, overshadowing the influence of the individual partner's education. Overall, the partner's education level does not seem to be a big factor in determining whether a woman prefers to have sons. The numeric estimates are provided in Appendix c.

Conclusion

This study aimed to understand how education influences the preference for having sons among Nepalese women and how this preference has changed over the past 27 years. I started by looking at the SRB spanning the past 27 years and focused on how female education and contextual factors contribute to mitigating son preference. In this study, we defined “son preference” as the desire to have more children even after reaching the idealized number, especially if no sons were born. This definition aligns with Arnold’s (1997) gender preference definition. The study included 39,039 women with at least two children and already achieved their idealized family size.

The result shows an increasing MBSRB over the period, supporting previous evidence of increasing sex-selective abortion in Nepal (Channon et al., 2021; Pradhan et al., 2019). Even though sex-selective abortion is illegal in Nepal, sex selection at birth seems apparent from the second birth order, and it gets pronounced with increasing birth order. This increasing MBSRB could be attributed to increasing norms of lower family size but the traditional values and importance associated with having a son. As the primary goal of this study is to investigate the influence of female education on the preference for having sons rather than the outcome itself, which is considered to be the result of that preference, the subsequent analysis looked into how the preference for having sons evolves over time among women of varying educational levels.

The finding suggests that female education not only reduces son preference among women but also exerts a broader influence beyond individual preferences, shaping the preferences of other women regarding the gender of their child. The study highlights a notable positive role of female education in reducing son preference, supporting the first hypothesis. This aligns with the results of a study conducted by Nguyen and Le in 2022 across 67 developing countries. Similar studies in India, Bangladesh, and Pakistan (Asadullah et al., 2021; Bose, 2012; Chowdhury, 1994; Raza, 2023) have demonstrated similar positive effects of women’s education on reducing son preference. However, it is essential to note that individual education alone is insufficient to eliminate son preference. Although a significant difference in son preference between educated and uneducated women was observed at the study’s beginning, this difference became less significant by the end. Despite this, son preference remains evident.

Community education, as characterized by the MYS in this paper, can be viewed as a proxy of social norms which can sometimes also act as a social pressure. The study shows that, regardless of no formal education, women who live in a community with a higher MYS have lower son preference. On the contrary, women living in a community with lower MYS have higher son preferences despite having higher education. This finding is consistent with the second hypothesis of this study, which is established based on the idea advanced by Cialdini & Goldstein (2004) that the collective behaviours of the majority in a society act as a norm. Individuals tend to follow this norm in order to gain acceptance and validation from their peers, neighbours or families to get a sense of belonging in their community. Therefore, changing educational composition can bring a shift in the norms regarding gender preference. As society progresses from lower to higher levels of education, the inclination toward son preference reduces among women of all education. It is crucial to recognize that son preference is influenced by the norms of the community where women reside. The process of change within a community norm is gradual, which takes time. However, investing in female education yields other various advantages beyond reducing son preference, including higher female labour force participation, thus contributing to the country's economy, empowering women to think rationally and to behave as they think, enhanced health outcomes for both mothers and children, a reduction in gender-based violence, and the bridging of gender inequality gaps.

While sex-selective testing of fetuses is prohibited in Nepal, the lack of effective law enforcement allows couples to abort female fetuses illegally (UNFPA, 2020). The government has enacted various laws to promote gender equality, including women's rights to ancestral property, reproductive rights, and reserved seats for women in the civil service. However, the implementation of these laws is often overshadowed by prevailing social rules and norms. There are also some programs that aim to reinforce regulations against violence related to women and children (Puri & Tamang, 2015). Besides these, a big economic aspect is still related to son preference in Nepal. The lack of effective old-age benefits and weak social security system is one of the major reasons that force parents to rely financially on their children, especially sons who co-reside with older parents. Since the patrifocal tradition compels daughters to move with their husbands and their husbands' families after marriage, having a son becomes crucial for parents seeking economic support in their old age. Therefore, investing in female education can provide a country with long-term demographic benefits, including a reduction in son preference, the establishment of effective social protection, and a comprehensive healthcare system that could hasten the reduction in son preference.

This study also offers an important suggestion to demographers, emphasizing the importance of female education in forecasting future sex ratios at birth in Nepal. The changing nature of son preference in relation to the changing educational composition of society emphasizes the need to incorporate both individual female education and the broader compositional effect of education while projecting SRB. Integrating these factors is likely to improve the accuracy of Sex Ratio at Birth (SRB) and population projections. However, further research on the direct impact of compositional effects of female education on SRB is important before making any concrete decision as the outcome is SRB rather than son preference. Such studies can provide more valid insights, allowing for more accurate predictions of future populations by incorporating individual and compositional education effects into population projection models.

References

Acharya, D. R. (2021). Status of Girls' Participation in Higher Education in Nepal. *International Journal of Multidisciplinary Perspectives in Higher Education*, *6*(2), Art. 2. https://doi.org/10.32674/jimphe.v6i2.3922

Acharya, D. R., Bell, J. S., Simkhada, P., van Teijlingen, E. R., & Regmi, P. R. (2010). Women's autonomy in household decision-making: A demographic study in Nepal. *Reproductive Health*, *7*(1), 15. https://doi.org/10.1186/1742-4755-7-15

Acharya, T. (2019). *Sex, Gender and Disability in Nepal: Marginalized Narratives and Policy Reform*. Routledge.

Arnold, F. (1997). *Gender preferences for children*. Macro International Incorporated.

Arnold, F., Choe, M. K., & Roy, T. K. (1998). Son Preference, the Family-building Process and Child Mortality in India. *Population Studies*, *52*(3), 301–315. https://doi.org/10.1080/0032472031000150486

Asadullah, M. N., Mansoor, N., Randazzo, T., & Wahhaj, Z. (2021). Is son preference disappearing from Bangladesh? *World Development*, *140*, 105353. https://doi.org/10.1016/j.worlddev.2020.105353

Asch, S. E. (1956). Studies of independence and conformity: I. A minority of one against a unanimous majority. *Psychological Monographs: General and Applied*, *70*, 1–70. https://doi.org/10.1037/h0093718

Bose, S. (2012). A Contextual Analysis of Gender Disparity in Education in India: The Relative Effects of Son Preference, Women's Status, and Community. *Sociological Perspectives*, *55*(1). https://doi.org/10.1525/sop.2012.55.1.67

Channon, M. D., Puri, M., Gietel-Basten, S., Stone, L. W., & Channon, A. (2021). Prevalence and correlates of sex-selective abortions and missing girls in Nepal: Evidence from the 2011 Population Census and 2016 Demographic and Health Survey. *BMJ Open*, *11*(3), e042542. https://doi.org/10.1136/bmjopen-2020-042542

Chowdhury, M. K. (1994). Mother's education and effect of son preference on fertility in Matlab, Bangladesh. *Population Research and Policy Review*, *13*(3), 257–273. https://doi.org/10.1007/BF01074337

Cialdini, R. B., & Goldstein, N. J. (2004). Social influence: Compliance and conformity. *Annual Review of Psychology*, *55*, 591–621. https://doi.org/10.1146/annurev.psych.55.090902.142015

Deuba, K., Mainali, A., Alvesson, H. M., & Karki, D. K. (2016). Experience of intimate partner violence among young pregnant women in urban slums of Kathmandu Valley, Nepal: A qualitative study. *BMC Women's Health*, *16*(1), 11. https://doi.org/10.1186/s12905-016-0293-7

Diamond-Smith, N., & Rudolph, K. (2018). The association between uneven sex ratios and violence: Evidence from 6 Asian countries. *PLoS ONE*, *13*(6), e0197516. https://doi.org/10.1371/journal.pone.0197516

Ebenstein, A. (2021). Elderly Coresidence and Son Preference: Can Pension Reforms Solve the 'Missing Women'Problem?. *Available at SSRN 3829866*.

Ebenstein, A., & Leung, S. (2010). Son Preference and Access to Social Insurance: Evidence from China's Rural Pension Program. *Population and Development Review*, *36*. https://doi.org/10.1111/j.1728-4457.2010.00317.x

Jin, X., Liu, L., Li, Y., Feldman, M. W., & Li, S. (2012, May). Gender imbalance, involuntary bachelors and community security: Evidence from a survey of hundreds of villages in rural China. In *Annual Meeting of the Population Association of America, May* (pp. 3-5). https://www.semanticscholar.org/paper/Gender-Imbalance-%2C-Involuntary-Bachelors-%2C-and-%3A-a-Feldman-Li/d1ebc72e74950bb214267a9e52070c54b1c641fe

Fledderjohann, J., & Channon, M. (2022). Gender, nutritional disparities, and child survival in Nepal. *BMC Nutrition*, *8*, 50. https://doi.org/10.1186/s40795-022-00543-6

Frost, M. D., Puri, M., & Hinde, P. R. A. (2013). Falling sex ratios and emerging evidence of sex-selective abortion in Nepal: Evidence from nationally representative survey data. *BMJ Open*, *3*(5), e002612. https://doi.org/10.1136/bmjopen-2013-002612

Gopalakrishnan, L., Bertozzi, S., & Rabe-Hesketh, S. (2023). Role of marriage, motherhood, son preference on adolescent girls' and young women's empowerment: Evidence from a panel study in India. *PLOS ONE*, *18*(9), e0292084. https://doi.org/10.1371/journal.pone.0292084

Gudbrandsen, N. H. (2013). Female Autonomy and Fertility in Nepal. *South Asia Economic Journal*, *14*(1), 157–173. https://doi.org/10.1177/1391561413477945

Guilmoto, Christophe. *Sex imbalances at birth: Current trends, consequences and policy implications*. Bangkok, Thailand:: UNFPA Asia and the Pacific Regional Office, 2012.Gupta, M. D. (1987). Selective Discrimination against Female Children in Rural Punjab, India. *Population and Development Review*, *13*(1), 77–100. https://doi.org/10.2307/1972121

Hazlett, C., & Wainstein, L. (2022). Understanding, Choosing, and Unifying Multilevel and Fixed Effect Approaches. *Political Analysis*, *30*(1), 46–65. https://doi.org/10.1017/pan.2020.41

Heath, R., & Jayachandran, S. (2016). *The causes and consequences of increased female education and labor force participation in developing countries* (No. w22766). National Bureau of Economic Research.

Javed, R., null, null, Mughal, M., & null, null. (2019). Have a Son, Gain a Voice: Son Preference and Female Participation in Household Decision Making. *The Journal of Development Studies*, *55*(12), 2526–2548. https://doi.org/10.1080/00220388.2018.1516871

Jayachandran, S. (2017, June 19). *Odds are you're measuring son preference incorrectly*. https://blogs.worldbank.org/impactevaluations/odds-are-you-re-measuring-son-preference-incorrectly

Jose, J., & Younas, J. (2023). Financial inclusion and women's bargaining power: Evidence from India. *International Review of Applied Economics*, *37*(1), 76–92. https://doi.org/10.1080/02692171.2022.2044459

Kien, L., & My, N. (2021). How Education Empowers Women in Developing Countries. *The B.E. Journal of Economic Analysis & Policy*, *21*(2), 511–536. https://ideas.repec.org//a/bpj/bejeap/v21y2021i2p511-536n5.html

Leone, T., Matthews, Z., & Zuanna, G. D. (2003). Impact and Determinants of Sex Preference in Nepal. *International Family Planning Perspectives*, *29*(2), 69–75. https://doi.org/10.2307/3181060

Lincove, J. Arnold. (2008). Growth, Girls' Education, and Female Labor: A Longitudinal Analysis. *The Journal of Developing Areas*, *41*(2), 45–68. https://doi.org/10.1353/jda.2008.0023

Lutz, W. (2017). Education empowers women to reach their personal fertility target, regardless of what the target is. *Vienna Yearbook of Population Research*, *15*, 27–31. https://www.jstor.org/stable/26506096

Lutz, W. (2022, June 6). Cognition-driven demographic transition. *N-IUSSP*. https://www.niussp.org/fertility-and-reproduction/cognition-driven-demographic-transition/

Medel-Anonuevo, C. (1995). *Women, Education and Empowerment: Pathways towards Autonomy. UIE Studies 5*.

Ministry of Health and Population, N., New ERA, & ICF. (2022). *Nepal Demographic and Health Survey 2022*. Ministry of Health and Population, Nepal. https://dhsprogram.com/publications/publication-PR142-Preliminary-Reports-Key-Indicators-Reports.cfm

Mitra, A. (2014). Son Preference in India: Implications for Gender Development. *Journal of Economic Issues*, *48*(4), 1021–1037. https://doi.org/10.2753/JEI0021-3624480408

Nguyen, M., & Le, K. (2022). Maternal education and son preference. *International Journal of Educational Development*, *89*, 102552. https://doi.org/10.1016/j.ijedudev.2022.102552

Nigatu, D., Gebremariam, A., Abera, M., Setegn, T., & Deribe, K. (2014). Factors associated with women's autonomy regarding maternal and child health care utilization in Bale Zone: A community based cross-sectional study. *BMC Women's Health*, *14*(1), 79. https://doi.org/10.1186/1472-6874-14-79

Pradhan, E., Pearson, E., Puri, M., Maharjan, M., Maharjan, D. C., & Shah, I. (2019). Determinants of imbalanced sex ratio at birth in Nepal: Evidence from secondary analysis of a large hospital-based study and nationally-representative survey data. *BMJ Open*, *9*(1), e023021. https://doi.org/10.1136/bmjopen-2018-023021

Puri, M., & Tamang, A. (2015). *Assessment of Interventions on Sex-Selection in Nepal: Literature Review*. CREHPA.Rai, P., Paudel, I. S., Ghimire, A., Pokharel, P. K., Rijal, R., & Niraula, S. R. (2014). Effect of gender preference on fertility: Cross-sectional study among women of Tharu community from rural area of eastern region of Nepal. *Reproductive Health*, *11*(1), 15. https://doi.org/10.1186/1742-4755-11-15

Raj, A., McDougal, L. P., & Silverman, J. G. (2015). Gendered Effects of Siblings on Child Malnutrition in South Asia: Cross-sectional Analysis of Demographic and Health Surveys from Bangladesh, India, and Nepal. *Maternal and Child Health Journal*, *19*(1), 217–226. https://doi.org/10.1007/s10995-014-1513-0

Raza, F. (2023). Do educated mothers have lower desired son preference? The case of Pakistan. *Women's Studies International Forum*, *99*, 102790. https://doi.org/10.1016/j.wsif.2023.102790

Sapkota, J. B., Paudel, D. B., Neupane, P., & Thapa, R. B. (2019). Preference for Sex of Children Among Women in Nepal. *Global Social Welfare*, *6*(2), 69–78. https://doi.org/10.1007/s40609-018-0117-9

Sheikh, S. M., & Loney, T. (2018). Is Educating Girls the Best Investment for South Asia? Association Between Female Education and Fertility Choices in South Asia: A Systematic Review of the Literature. *Frontiers in Public Health*, *6*. https://doi.org/10.3389/fpubh.2018.00172

Stromquist, N. P. (2015). Women's Empowerment and Education: Linking knowledge to transformative action. *European Journal of Education*, *50*(3), 307–324. https://www.jstor.org/stable/26609280

The Kathmandu Post. (2023, May 21). *Gender bias forcing women into sex-selective abortions*. http://kathmandupost.com/province-no-5/2022/01/13/gender-bias-forcing-women-into-sex-selective-abortions

UNFPA. (2020). *PREVENTING SON PREFERENCE AND UNDERVALUING OF GIRLS IN ASIA PACIFIC*. https://www.semanticscholar.org/paper/PREVENTING-SON-PREFERENCE-AND-UNDERVALUING-OF-GIRLS/46d3cd4b2ab87921a70aaf7bf31682c12852cba5

Weitzman, A. (2020). The Sex of Firstborn Children and Intimate Partner Violence in India. *Violence Against Women*, *26*(6–7), 590–613. https://doi.org/10.1177/1077801219833823

Yi, Z., Ping, T., Baochang, G., Yi, X., Bohua, L., & Yongpiing, L. (1993). Causes and Implications of the Recent Increase in the Reported Sex Ratio at Birth in China. *Population and Development Review*, *19*(2), 283. https://doi.org/10.2307/2938438

‘

Appendix

Appendix A: Average Marginal effect from regression Model 1

Variables	Labels	Average marginal effect (LL - UL)			
		No education	Primary	Secondary or above	All women
Intercept	Intercept				
Gender composition of already-born children (ref= “Both”)	Only daughter/s	0.3414*** (0.3174-0.3654)	0.2647*** (0.2399-0.2894)	0.2844*** (0.2537-0.3149)	0.306*** (0.290-0.322)
	Only son/s	0.0043 (-0.0026- 0.011)	0.0453*** (0.0346-0.056)	0.026** (0.0144-0.0377)	0.02*** (0.015 - 0.026)
Parity (ref= “Two”)	One	0.0543** (0.034- 0.074)	0.0627*** (0.047 - 0.0784)	0.0563*** (0.035 - 0.077)	0.06*** (0.05 -0.0712)
	Three or more	-0.0358*** (-0.044- -0.027)	-0.0287*** (-0.042 - 0.015)	-0.0139* (-0.0256 -0.002)	-0.0219*** (-0.027 - -0.016)
Five-year survey period	Survey period	-0.0029*** (-0.003- -0.002)	0.0002 (-0.0005-0.001)	-0.001** (-0.0016--0.0004)	-0.0023*** (0.0025 - -0.002)

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

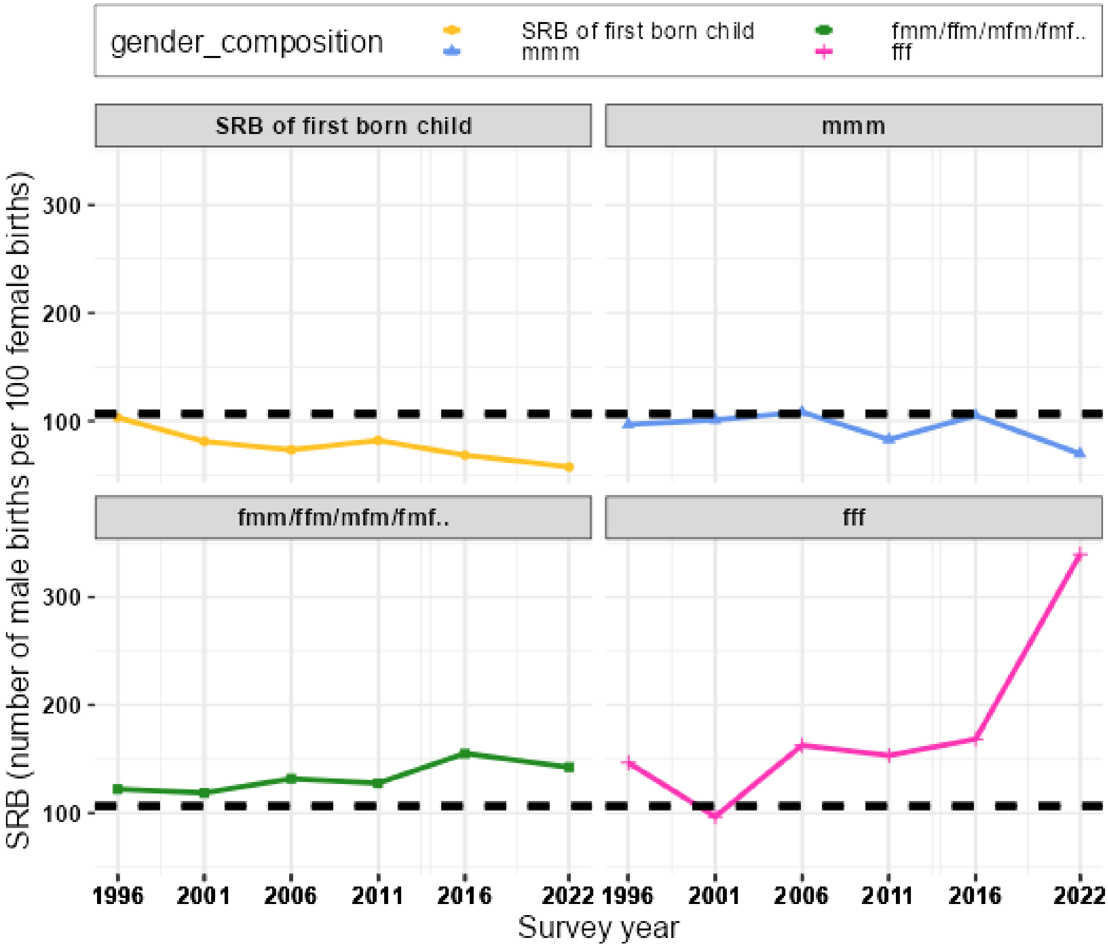
Appendix B: Average Marginal effect from regression Model 2

Variables	Labels	Average marginal effect (LL - UL)			
		No education	Primary	Secondary or above	All women
community education	MYS	-0.02*** (-0.023 - -0.017)	-0.009*** (-0.014--0.005)	-0.013*** (-0.017--0.009)	-0.018*** (-0.021 - -0.016)
Gender composition of already-born children (ref= "Both")	Only daughter/s	0.34*** (0.313 - 0.367)	0.275*** (0.247-0.304)	0.292*** (0.257-0.328)	0.317*** (0.297 - 0.338)
	Only son/s	0.003 (-0.004 - 0.01)	0.045*** (0.033-0.056)	0.026*** (0.014-0.038)	0.018*** (0.012 - 0.024)
Parity (ref= "Two")	One	0.059*** (0.037 - 0.081)	0.069*** (0.052-0.086)	0.058*** (0.037-0.08)	0.07*** (0.058 - 0.082)
	Three or more	-0.042*** (-0.051 - -0.033)	-0.034*** (-0.048--0.021)	-0.019*** (-0.031--0.007)	-0.033*** (-0.039 - -0.027)

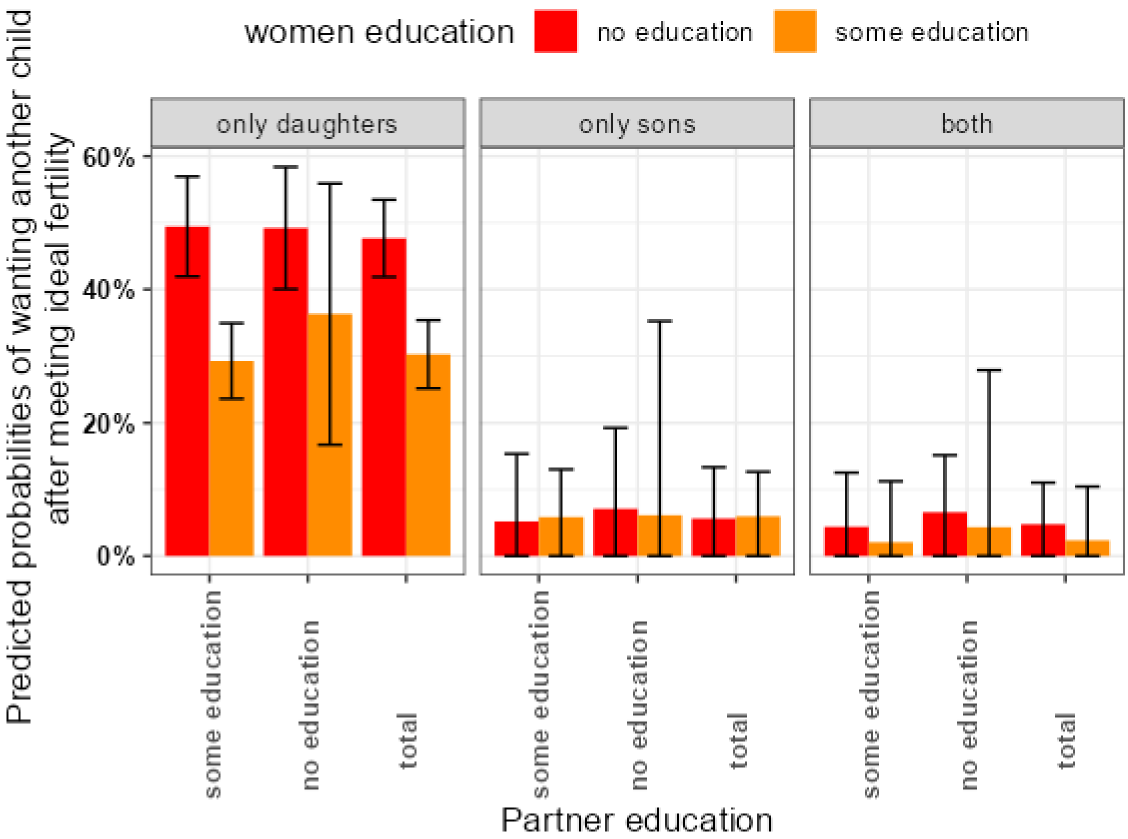
Appendix C: Average Marginal effect from regression Model 3

Variables	Labels	Average marginal effect (LL - UL)		
		Partner's education		
		No education	Some education	Total
Intercept	Intercept			
Gender composition of already-born children (ref= "Both")	Only daughter/s	0.278*** (0.213-0.343)	0.288*** (0.268-0.308)	0.288*** (0.268-0.307)
	Only son/s	0.011 (-0.01-0.032)	0.033*** (0.025-0.041)	0.03*** (0.023-0.037)
Parity (ref= "Two")	One	0.053** (0.001-0.104)	0.06*** (0.048-0.072)	0.059*** (0.048-0.071)
	Three or more	-0.033*** (-0.056--0.009)	-0.017*** (-0.025--0.008)	-0.018*** (-0.026--0.01)
Women's education (ref= "no education")	Some education	0.008 (-0.011-0.027)	-0.021*** (-0.034--0.008)	-0.016*** (-0.026--0.006)

Appendix D: Trend in SRB of lastborn child and firstborn child by the gender composition of siblings among women with 4 children



Appendix E: Desire to have additional children by women's and their partners' education, stratified by the sex composition of their previously born children



3 Conclusion

3.1 Main findings

This overall doctoral project contributes to understanding and making better scientific assumptions regarding specific determinants that partially explain the heterogeneity in fertility and can be used as the dimension of a multidimensional population projection model to make the population project more accurate. Education and urbanization were two additional dimensions beyond age and sex that have gained increased attention from scholars in the field of population heterogeneity. As none of the organizations producing global population projection added the effect of urbanization and education explicitly on future fertility, this dissertation aims to fill the research gap by systematically investing in the need to add these dimensions while projecting future fertility and by providing empirical evidence to build the scientific assumptions regarding the effect of these additional education and urbanization dimensions on current and future fertility.

In the global population projection trends, experts usually project how urban population proportion will grow without considering other important factors such as age, sex, and education levels (KC et al., 2018; Ritchie & Roser, 2018). This dissertation highlights the need to understand how education and the place of residence affect the number of children together. The main finding is that when making this projection, it is important to consider both the education as well as the place of residence. Even though the estimates have shown that higher education is linked to living in urban areas, we cannot assume that just looking at urban or rural areas covers the education differences or vice versa. The model should consider both education and the place of residence while forecasting the fertility rates. The numeric estimates found in the study and the rural and urban fertility differences observed across different stages of fertility transition can be useful for the multidimensional fertility projection model to project the future fertility in both rural and urban regions for each education group. The U-shaped pattern observed across different demographic transition periods (shown by using the urban fertility rate as a proxy of the transition period) can be applied to make an assumption for the difference in the total fertility rate between rural and urban regions at different periods. The absolute difference between the fertility rates of rural and urban regions given for high and low education can also be applied to project different fertility trajectories by education in rural and urban areas. Literature has established a different mechanism for why people have fewer children due to women's education. However, we do not know as much about how urban living affects family size. Aside from obvious reasons such as higher housing costs and more women working (which is linked to education), there are other reasons related to how people learn from one another and how ideas spread, as explained in the literature on diffusion of fertility.

Looking specifically at Africa, we see that the idea and behaviour of having fewer children diffuses from one group to another. Women with more education started this trend, spreading to women with less education who live close to higher educated women. Our careful robustness check supports this strong diffusion effect in different regions (cluster, strata, national) of Africa. Using the time series data on education-specific TFR, this dissertation showed that the fertility behaviour of one educational group affecting another could be modelled to forecast future fertility. This new method captures two important phenomena about fertility that the agencies producing global population projection mentioned in the introduction of this dissertation lack. First, it considers the social learning effect, which is the inherent behaviour of a human being. Second, it also captures the explicit effect of education on fertility. Using the diffusion rate to project the future TFR in Kenya and Nigeria showed that the diffusion effect can capture the impact of changing educational composition on future fertility rates. However, there is still a need for a solid scientific assumption regarding the effect size of diffusion on fertility when countries transition to a higher level of education, like in many low-fertility countries.

The influence of social learning behaviours extends beyond shaping the preferences and number of children women have; it also affects the gender preference for children. From the analysis of Nepal Demographic and Health Survey data, I observed that less educated women residing in communities with higher MYS tend to exhibit a reduced inclination toward preferring sons, a characteristic typically associated with more educated women, and vice versa. Notably, the influence of these social learning effects on son preference outweighs the influence of individual educational levels. While investing in female education may not immediately diminish son preference significantly, it yields long-term benefits by reshaping societal norms, leading to a reduction in gender preference over time. Beyond addressing gender bias, educational investments also contribute to increased female labour force participation, financial independence, women empowerment, and improved access to modern contraception. These factors can directly or indirectly influence gender preference.

Moreover, son preference can lead to a male-biased sex ratio at birth in low-fertility settings, particularly in societies where couples desire fewer children but still prioritize having a son. Therefore, forecasting the SRB in countries like Nepal, where societal values favour sons over daughters, requires careful consideration and further analysis of the role of education and social learning behaviour in SRB.

In conclusion, this dissertation emphasizes the critical role of female education in shaping fertility dynamics and the need to refine existing fertility projection models to enhance accuracy and comprehensiveness. Using data from lower and middle-income countries, this study particularly focuses on the impact of female education, urbanization, and diffusion processes on fertility. The finding highlights the additional effect of urbanization on fertility beyond female education, emphasizing the necessity of incorporating urbanization as a dimension in the multidimensional fertility projection model. As the mechanism underlying urbanization might be attributed to the diffusion process, the study introduces a novel method that captures the diffusion processes within education groups, emphasizing its importance in fertility projections and showcasing its potential to address gaps in existing models. The dissertation further implies a similar concept of social learning to study son preference in Nepal, revealing the potential for educational interventions to mitigate gender preference at birth. These findings contribute to a deeper understanding of fertility determinants, offering insights for policymakers, organizations, and scholars working towards population projection and sustainable development. By addressing research gaps and proposing innovative methodologies, this dissertation provides a foundation for more accurate fertility projections that consider the evolving landscape of education, urbanization, and social learning effects crucial for informed decision-making and strategic planning in the face of demographic and socio-economic changes.

Finally, education is important to understand human beings, their behaviour, and their skills or capacities for adaptation and mitigation of any potential risk in the future. Above all, education (formal/informal) shapes the way we think and, in turn, influences how we act and see the world. Education works as the architect of our thoughts, constructing the very framework of our minds. So, education should be our go-to guide when it comes to understanding and dealing with risks. I end this dissertation by quoting Nelson Mandela's saying, "Education is the most powerful weapon which you can use to change the world."

3.2 Acknowledgement

This PhD project was a big step for me, stepping into the world of research and academia for the first time. I dedicated a lot of time to learning and updating my skills to match the research goals of my doctoral project. This thesis would not have come together without the help of the wonderful people at the International Institute for Applied System Analysis and the University of Vienna.

I want to express my gratitude to the many colleagues, friends, and supervisors who supported and guided me and encouraged me to give it my all. A special acknowledgement goes to my thesis supervisors, Prof. Wolfgang Lutz and Prof. Samir KC, for their unwavering support, guidance, and encouragement throughout my PhD journey. Additional thanks to Prof. Samir KC for being a guiding hand and helping me take small steps in the research world. Everything I have learned can be attributed to your support and mentorship.

A big thanks go to Aayushma KC for always lending a hand with proofreading and reviewing my work, from regular assignments to papers for this PhD project. Last but not least, a special thanks to my husband, Pawan Lamsal, for your love and support. You have been my rock through the highs and lows of this academic journey so far. I would not have been me without you.