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Neighbourhood mothers' education and its differential impact on stunting: Evidence from 30 Sub-Saharan African countries

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ABSTRACT

The study used data from Demographic and Health Surveys for 30 Sub-Saharan African countries to investigate differences in the residential effects of mothers' education on stunting. Multilevel logistic regressions were employed to examine the neighbourhood effects of mothers' education on stunting. The study found that although a higher proportion of mothers with secondary education in a neighbourhood, irrespective of the residence type (rural or urban), reduces a child's probability of being stunted, this effect is stronger for children residing in rural areas than those in the urban. Achieving a target of at least 75 per cent of mothers obtaining secondary education and higher will bridge the rural-urban gap in stunting in Sub-Saharan Africa.

1. Introduction

Stunting in the first five years of life impairs a child's development, which affects the cognitive skills needed for academic achievement and economic productivity (Ekholuenetale et al., 2020; Grantham-McGregor et al., 2007; Koshy et al., 2022). The term stunting, commonly referred to as chronic malnutrition, is defined as a height-for-age z-score that is less than two standard deviations from the median of the World Health Organization (WHO) child growth standard (World Health Organization, 2006). It is a standard indicator of malnutrition in early childhood and is prevalent in many parts of Africa and Asia (Ahmed et al., 2012; Dewey and Begum, 2011). Despite a significant reduction in stunting rates across the globe in recent years, the current prevalence remains higher than the desired global rates, which is a cause for concern. Globally, there has been a decline in stunting rates from 33 per cent in 2000 to 22 per cent in 2020. However, the reduction in rates has not been equal across regions. While Asia saw a about 41 per cent decline – from 37 per cent in 2000 to 21 per cent in 2020, Africa recorded a 26 per cent decline – from 42 per cent to 31 per cent (UNICEF, WHO, & World Bank Group, 2021). Within the same period, between 2000 and 2020, the number of stunted children declined in all regions except Africa. The number of stunted children in Africa increased from 54.4 million in 2000 to 61.4 million in 2020.

It is increasingly recognised that in the first two (2) years of a child's life, linear growth rates could be significantly influenced by potentially amendable factors in their surroundings: social, economic, cultural and other environments. (Bernard et al., 2007; de Onis and Branca, 2016; Earls and Carlson, 2001; Maggi et al., 2010).

Over the years, mothers' education has gained considerable attention among the factors influencing child health, primarily due to its policy implications. Empirically, there is a modest contention among researchers on the effect of mothers' education and child health regarding the appropriate level of education. However, from a theoretical perspective, a consensus affirms the effect of mothers' education on child health.

A major pathway through which a mother's education may affect child health is through socioeconomic factors (Alemayehu Azeze and Huang, 2014; Grépin and Bharadwaj, 2015; Keats, 2018). Evidence from Zimbabwe suggests that increased education levels improve women's economic opportunities (Grépin and Bharadwaj, 2015). Women who are more educated are likely to get better jobs and increase household wealth (Keats, 2018). It is also evident that uneducated people often find work in the informal market, while educated people are placed in the formal sector and earn higher wages (El Badaoui and Rebiere, 2013).

In line with the channel relating to socioeconomic status, education may promote empowerment and autonomy (Dito, 2015; Jejeboy, 1992). Education has been proven to afford women relatively better positions in the household (Thomas, 1990) and enhances women's abilities to participate in decision-making processes (Behrman, 2015).

Other studies have identified personal illness control and attitude towards healthcare as a pathway (Basu and Stephenson, 2005; Desai and Alva, 1998; Musaddiq and Said, 2023). Basu and Stephenson (2005)

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argued that maternal education significantly affects healthcare-related behaviours, such as seeking and receiving prenatal care through pregnancy and seeking medical care for the treatment of a child's fever or cough. In Uganda, children with educated mothers are more likely to receive immunisation shots and vitamin A supplements to support healthy immune systems and prevent blindness (Desai and Alva, 1998; Keats, 2018). Mothers' education is also related to more beneficial health investment behaviours at each phase of a child's early development, thereby improving the health and well-being of the child (Prickett and Augustine, 2016).

Another pathway through which mothers' education can affect child health is the adoption of modern attitudes and practices towards health. As Andriano and Monden (2019) outlined, education facilitates the acceptance of rational explanations of illness and the adoption of modern medical treatments and practices. Women who are educated, therefore, are more likely to find effective health care for the treatment of diseases for their children (Basu and Stephenson, 2005; Glewwe, 1999). Education reduces traditional and harmful treatment practices, such as withholding fluids during diarrhoea (Bicego and Boerma, 1990).

Glewwe (1999) asserted that formal education confers health knowledge on future mothers, acquiring skills in diagnosing and treating some common child-related diseases and being more receptive to modern medicine. Education thus improves mothers' health knowledge on the use and effectiveness of contraceptives (Rosenzweig and Schultz, 1989), how HIV spreads and its preventive measures (Agüero and Bharadwaj, 2014) and the most appropriate prenatal practices (Basu and Stephenson, 2005; Grossman, 1972). In Ghana, Frempong and Annim (2017) found that mothers with at least primary education are more likely to feed their children with a diversified diet that improves their health than those without education.

Environmental factors provide another pathway through which maternal education may affect child health outcomes (Andriano and Monden, 2019; Emina et al., 2009). The authors argued that educated women tend to live in more environmentally clean areas. Such women are mindful of the implications of poor sanitation and hygiene practices and are therefore successful at mitigating the incidence of diseases such as diarrhoea (Andriano and Monden, 2019; Hatt and Waters, 2006; Hobcraft, 1993). Desai and Alva (1998) indicated that women with higher educational attainments purposefully choose to live in communities with improved amenities and good medical facilities.

Chen and Li (2009) examined whether the maternal education effect on a child is a nurturing effect. The authors found that, compared to their own children, the effect of a mother's education on adopted children (who are genetically unrelated to the mother) shows no differential effect, suggesting that a mother's education has mostly post-natal nurturing effect on child health.

Premised on these substantive pathways and arguments, several studies from Ghana (Addai, 2000; Benefo and Schultz, 1996; Greenaway et al., 2012; Kanmiki et al., 2014; Nakamura et al., 2011), Sub-Saharan Africa (Caldwell and McDonald, 1982; Casale et al., 2018; Fadare et al., 2019; Yaya et al., 2019) and other parts of the world (Emamian et al., 2014; Garcia et al., 2013; Stamenkovic et al., 2016) also found a significant effect of mother's education on child health. However, these studies only considered the effect of an individual mother's education on their offspring – overlooking the salience of social capital and externalities that may broaden the effect of mothers' education on other children in close geographic proximity through the sharing of health-related knowledge with other mothers and copycatting of good health behaviours and practices by other mothers.

This study sets out to (1) examine the effect of neighbourhood mothers' education on child stunting over and above the child's own mother's education and (2) Investigate differences in the neighbourhood effects of mothers' education on stunting. With emphasis on the contextual effect of neighbourhood mothers' education, data from 30 Sub-Saharan African countries is used to analyse the role of neighbourhood effects and variations with regard to child health.

2. Methods

2.1. Data source

The study used the Demographic and Health Survey datasets from 30 Sub-Saharan African countries. Out of a total of 41 Sub-Saharan countries' data available, the study excluded seven countries with restricted datasets and four without GPS data or location coordinates. Table 1 shows the countries, survey years and the number of children sampled for the study. The study included survey years between 2010 and 2020. Madagascar was the only exception made. The study used the 2008 DHS data for Madagascar. However, this was only used in the spatial analysis but not for other analyses. A sample of 245,426 children (72,544 from urban areas and 172,882 from rural areas) below 5 was used in the spatial analysis, while 233,314 were used in the multilevel analyses. Appendix 1 shows the locations of sampled clusters across countries in Sub-Saharan Africa. A total of 15,583 clusters were considered in this study.

The data have a clustered or hierarchical structure, so observations may be more similar in their social characteristics. Thus, individual children nested within geographical areas may have similar characteristics. The study used spatial analysis and multilevel models to recognise the existence of clustering in the data. If the prevalence of stunting is clustered by geographical area, and this is not taken into account in the estimation as in the traditional logistic regression, the standard errors of the regression coefficients will generally be underestimated (McNeish, 2014). To obtain correct standard errors, variation among groups is allowed in the analysis. Multilevel models provide efficient means of controlling for clustering and allow for the residual components at each level in the hierarchy, as shown in Eq. (1).

A two-level model was used to allow for the grouping of childhood stunting within geographical areas to include residuals at the child level and the geographical area (or neighbourhood) level. The dependent variable is binary, where 0 is the response for a child who is not stunted and 1 is for stunted. Table 2 presents the description of the variables

Table 1
Countries, survey years and sampled under-5 children.

	Country	Survey year	Sampled under 5 Children
1	Angola	2016	9582
2	Benin	2012	11,995
3	Burkina Faso	2010	6380
4	Burundi	2011	3588
5	Cameroon	2011	5079
6	Chad	2015	10,680
7	Comoros	2012	2739
8	Congo, Democratic Rep.	2014	7776
9	Cote d'Ivoire	2012	3330
10	Ethiopia	2010	19,180
11	Gabon	2012	3511
12	Ghana	2014	2685
13	Guinea	2012	3225
14	Kenya	2014	18,869
15	Lesotho	2014	2940
16	Liberia	2016	5283
17	Madagascar	2008	12,112
18	Malawi	2016	10,344
19	Mali	2016	4861
20	Mozambique	2016	9715
21	Namibia	2013	1902
22	Nigeria	2015	27,161
23	Rwanda	2015	7685
24	Senegal	2015	9980
25	Sierra Leone	2013	4958
26	Tanzania	2016	15,516
27	Togo	2014	3214
28	Uganda	2015	2150
29	Zambia	2014	12,034
30	Zimbabwe	2015	19,064
	Total		245,426

Table 2
Variable description.

Variable	Definition	Measurement	Abbreviation
Child age	Age of the child in categories	measured as 0 =< 6; 1 = 6–8; 2 = 9–11; 3 = 12–17; 4 = 18–3; 5 = 24–35; 6 = 36–47; 7 = 48–59	Child_age
Sex of child	Gender of child	1 = male; 2 = female	Child_sex
Size at birth	Size of the child on delivery	0 = very small; 1 = small; 2 = Average	Size_at_birth
Mother's education	Mother's highest educational attainment	0 = No education; 1 = Primary; 2 = Middle/ Secondary; 3 = higher	Mothers_educ
Mother's age	Age of the Mother of the child	Measured in years. Ranges from 15 to 45 years	Mothers_age
Improved water source	Source of drinking water	0 = not improved; 1 = improved	Imp_water
Improved sanitation	Improved toilet facility	0 = not improved; 1 = improved	Imp_sanitation
Wealth	An index of the wealth status of the household	0 = Poorest; 1 = Poorer; 2 = Middle; 3 = Richer; 4 = Richest	wealth
Age of head of household	Age of the head of household	measured in years. ranges from 15 years to 95 years	Hhh_age
Ever Breastfed	Was child ever breastfed	yes = 0; no = 1	Ever_breastfed
Residence	Residence status of the household	1 = urban; 2 = rural;	residence
Altitude	Cluster's elevation in meters above sea level	Measured in meters. Ranges from −92 to 3563 m	Altitude
Proportion of mothers with secondary levels of education	Proportion of mothers with at least secondary levels of education in each cluster	Aggregated individual mothers' with secondary education at the cluster level	Mothers_educ2_means
Proportion of mothers with higher levels of education	Proportion of mothers with higher levels of education in each cluster	Aggregated individual mothers' with higher education at the cluster	Mothers_educ3_means

used in the analysis.

2.2. Model specification

First, the multilevel model without the contextual effect of the proportion of mothers' education is specified as:

$$\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_0 + \beta_1 child\_age_{ij} + \beta_2 child\_sex_{ij} + \beta_3 size\_at\_birth_{ij} + \beta_4 mothers\_educ_{ij} + \beta_5 mothers\_age_{ij} + \beta_6 imp\_water_{ij} + \beta_7 imp\_sanitation_{ij} + \beta_8 wealth_{ij} + \beta_9 hhh\_age_{ij} + \beta_{10} ever\_breastfed_{ij} + \beta_{11} residence_j + \beta_{12} altitude_j + \mu_{0j} \quad (1)$$

The study then estimates two random intercept models introducing the contextual effect of mothers' secondary and higher education (Eqs. (2) and (3), respectively). These are to test that neighbourhood mothers' education positively affects a child's health status over and above the effect of their own mother's level of education:

$$\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_0 + \beta_1 child\_age_{ij} + \beta_2 child\_sex_{ij} + \beta_3 size\_at\_birth_{ij} + \beta_4 mothers\_educ_{ij} + \beta_5 mothers\_age_{ij} + \beta_6 imp\_water_{ij} + \beta_7 imp\_sanitation_{ij} + \beta_8 wealth_{ij} + \beta_9 hhh\_age_{ij} + \beta_{10} ever\_breastfed_{ij} + \beta_{11} residence_j + \beta_{12} altitude_j + \beta_{13} mothers\_educ2\_means_j + \mu_{0j} \quad (2)$$

$$\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_0 + \beta_1 child\_age_{ij} + \beta_2 child\_sex_{ij} + \beta_3 size\_at\_birth_{ij} + \beta_4 mothers\_educ_{ij} + \beta_5 mothers\_age_{ij} + \beta_6 imp\_water_{ij} + \beta_7 imp\_sanitation_{ij} + \beta_8 wealth_{ij} + \beta_9 hhh\_age_{ij} + \beta_{10} ever\_breastfed_{ij} + \beta_{11} residence_j + \beta_{12} altitude_j + \beta_{13} mothers\_educ3\_means_j + \mu_{0j} \quad (3)$$

The study further tests the interaction effect of residence and the proportion of mothers with at least secondary education. Thus, Eq. (4) tests the main hypothesis that the relationship between the proportion of mothers' education (secondary education) and child stunting is mediated by the residence of the child.

$$\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_0 + \beta_1 child\_age_{ij} + \beta_2 child\_sex_{ij} + \beta_3 size\_at\_birth_{ij} + \beta_4 mothers\_educ_{ij} + \beta_5 mothers\_age_{ij} + \beta_6 imp\_water_{ij} + \beta_7 imp\_sanitation_{ij} + \beta_8 wealth_{ij} + \beta_9 hhh\_age_{ij} + \beta_{10} ever\_breastfed_{ij} + \beta_{11} residence_j + \beta_{12} altitude_j + \beta_{13} mothers\_educ2\_means_j + \beta_{14} mothers\_educ2\_means\#residence_j + \mu_{0j} \quad (4)$$

where, β_{14} is the interaction effect of the proportion of mothers with secondary education and residence.

3. Results

3.1. Descriptive findings

3.1.1. Inequalities in Sub-Saharan Africa

In the Sub-Saharan African context, rural-urban disparities are evident. In terms of aggregates, about 78 per cent of stunted children in Sub-Saharan Africa reside in rural areas. With regards to wasting, about 74 per cent of under-5 wasted children reside in rural areas, while 26 per cent are found in urban areas (Appendix 2). Again, the table shows that approximately 79 per cent of under-five underweight children in Sub-Saharan Africa reside in rural communities, while approximately 21 per cent reside in urban areas. Fig. 1 presents the distribution of stunted children in rural and urban residences in Sub-Saharan Africa. The graph shows that with the exception of Gabon, which has a little more stunted children in the urban areas compared to the rural areas, Sub-Saharan African countries have more stunted children in the rural areas compared to their urban areas. More striking are the rural-urban differences compared to the national average in countries like Burundi, Malawi, Ethiopia, Rwanda and Uganda. In Burundi, the national stunting prevalence is 55 per cent. However, 12 per cent of these stunted children live in urban communities, while 88 per cent reside in rural areas. The national prevalence of stunting in both Malawi and Ethiopia is about 40 per cent, out of which 90 per cent reside in the rural areas and 10 per cent in the urban areas.

In Rwanda, the rural-urban distribution of stunted children is 89 per cent and 11 per cent, respectively; the national prevalence is 41 per cent. Uganda recorded a similar rural-urban disparity: while the national stunting prevalence rate was 33 per cent, the country recorded about 88 per cent residing in the rural areas and approximately 12 per cent living

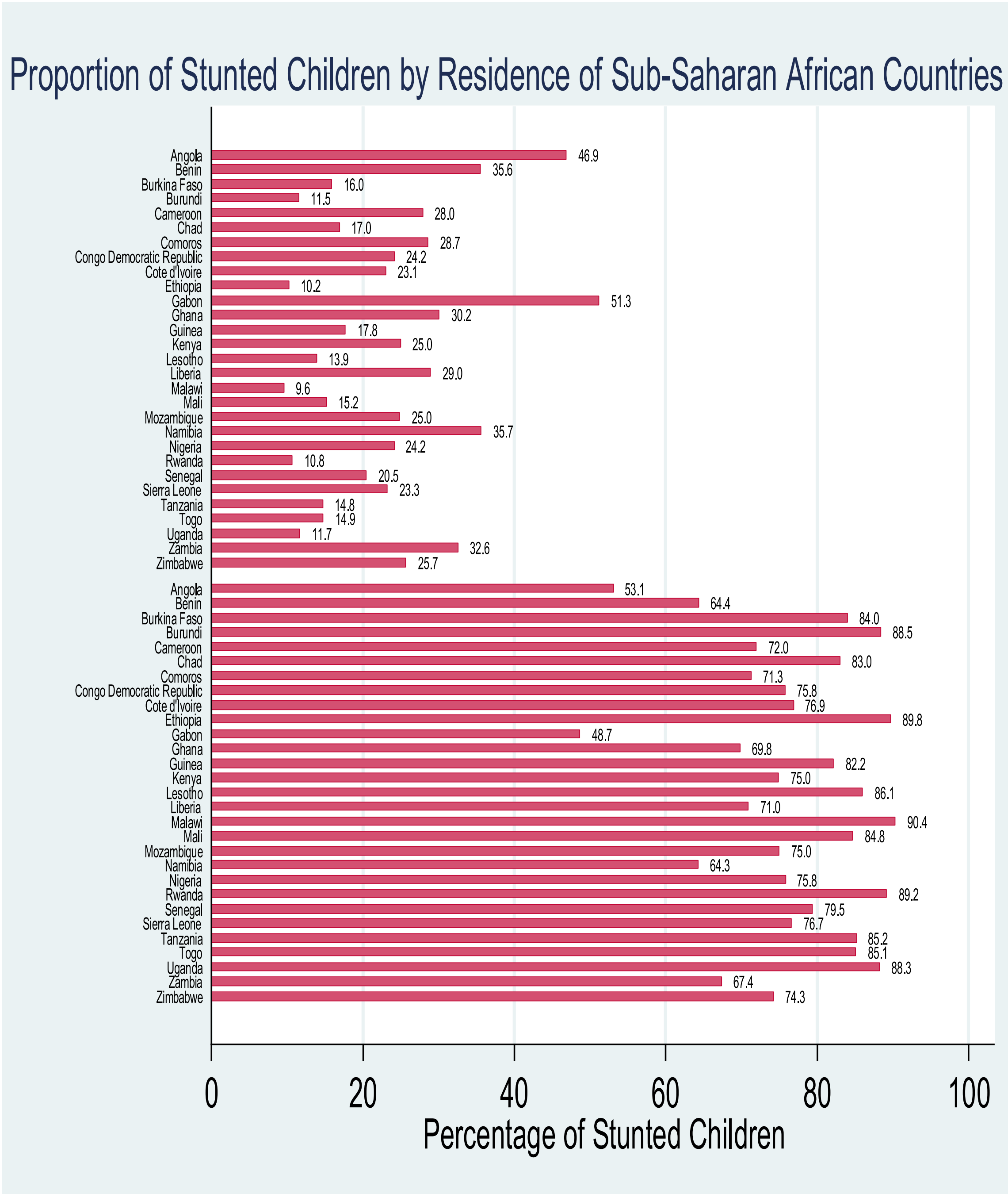

Fig. 1. Distribution of stunted children by residence (urban-rural) of Sub-Saharan African countries.
Source: Author's computations from Demographic and Health Surveys.

in the urban areas. This shows the persistence of rural-urban disparities in under-5 children's stunting rates in Sub-Saharan Africa.

3.2. Bivariates

Table 3 presents the bivariate analysis results, testing the association between the independent variables and stunting. The results show that 15 per cent of children below 6 months are stunted as compared to 17 per cent of children from 6 to 8 months old, 23 per cent of children from 9 to 11 months old and 33 per cent of children from 12 to 17 months old. Out of 21,143 children aged 18–23 months, 44 per cent are stunted, which is lower than the percentage of stunted children aged 24–35 months, 36–47 months, and 48–59 months – thus, recording 45 per cent, 41 per cent and 36 per cent respectively. These show statistically significant differences in the prevalence of stunting across the different age groups. Most importantly, it is observed that the proportion of stunted children increases with age up to 35 months and then falls, suggesting a non-linear relationship between child age and stunting.

The results also show that the proportion of stunted male children is higher than females. Approximately 48 per cent of male children are stunted, while about 33 per cent of female children are stunted. This suggests that male children are more vulnerable than females and could be attributed to differences in biological make-up and possibly some behavioural factors (Cronk, 1989; Garenne, 2003) like dietary

Table 3
Bivariate analysis for statistical association between the independent variables and stunting.

	Stunted		Not stunted	
	%	Number of children	%	Number of children
Child age				
<6	14.64	3207	85.36	18,696
6–8	17.09	2152	82.91	10,440
9–11	23.44	2779	76.56	9076
12–17	33.10	8238	66.90	16,649
18–23	44.27	9360	55.73	11,783
24–35	45.28	19,550	54.72	23,627
36–47	41.36	17,881	58.64	25,351
48–59	35.40	14,550	64.29	26,190
Chi square	10000.00 (Pr = 0.00)			
Sex of child				
Male	37.83	41,687	62.17	68,520
female	32.96	36,030	67.04	73,292
Chi square	568.79 Pr = (0.00)			
Size at birth				
Very small	44.38	5475	55.62	6863
Small	42.09	9080	57.91	12,492
Average or larger	34.24	59,104	65.76	113,505
Chi square	948.64 (Pr = 0.00)			
Mother's education				
No education	41.34	34,914	58.66	49,534
Primary	36.64	29,849	63.36	51,613
Secondary	25.60	12,205	74.40	35,470
Higher	12.54	743	87.46	5184
Chi square	4700 (Pr = 0.00)			
Water source				
Not improved	40.62	34,038	59.38	49,759
Improved	32.18	43,679	67.82	92,053
Chi square	1600 (Pr = 0.00)			
Sanitation				
Not improved	39.17	54,359	60.83	84,432
Improved	28.93	23,358	71.07	57,380
Chi Square	2300 (Pr = 0.00)			
Household wealth				
Poorest	42.31	23,507	57.69	32,054
Poorer	39.73	18,983	60.27	28,799
Middle	36.29	15,544	63.71	27,286
Richer	31.26	12,525	68.74	27,539
Richest	21.50	7158	78.50	26,134
Chi square	4700 (Pr = 0.00)			
Breastfeeding				
Ever breastfed	35.67	72,879	64.33	131,439
Never breastfed	38.55	1750	61.45	2789
Chi Square	16.098 (Pr = 0.00)			
Residence				
Urban	26.50	16,877	73.50	46,798
Rural	39.04	60,840	60.96	95,014
Chi square	3100 (Pr = 0.00)			

discrimination (Leslie et al., 1997).

On the association between size at birth and stunting, the results show that stunting varies significantly for the various size categories of children at birth; 44 per cent of children who were very small at birth are stunted, and 42 per cent of those who were small. Comparatively, the rate drops further to 34 with stunted children who were average or larger at birth.

In the context of the mother's education levels, significant variations in stunting are observed for the respective levels. The proportion of stunted children tends to be higher for children whose mothers have a lower level of education. Table 3 shows that about 41 per cent of children whose mothers have no educational background are stunted. These are relatively high compared with children whose mothers have, at most, primary education. Of these children, 37 per cent are stunted. With respect to mothers with a secondary level of education, approximately 1 out of every 4 children is stunted. Among the various groups of mothers' education levels, the proportions of stunted children are lowest for those whose mothers have higher education levels. For this group, 13 per cent are stunted. This suggests that children of mothers with higher levels of education are less susceptible to poor health. This could be attributed to increases in household income as well as literacy, leading to the acquisition and effective consumption of information (Thomas et al., 1991).

The results also show a significant association between the source of drinking water and stunting. About 41 per cent of children from households without an improved source of drinking water are stunted. However, among children from households with an improved source of drinking water, 32 per cent are stunted. Similarly, child health tends to have a significant association with sanitation. Approximately 39 per cent of children from households without improved sanitation are found to be stunted. Of the proportion of children from households with improved sanitation, however, about 29 per cent are stunted. This trend of association can be attributed to the conception that improved water and sanitation reduce infectious diseases that are linked to poor health (Dangour et al., 2013).

The results also show wealthier households have children with better health statuses than poorer ones. Regarding the various categories of wealth status of households (poorest, poorer, middle, richer and richest), the proportion of stunted children is approximately 42 per cent, 40 per cent, 36 per cent, 31 per cent and 22 per cent, respectively.

More striking are the differences in the association between place of residence and health status. It is observed that 27 per cent of children residing in urban areas are stunted, while 39 per cent of those living in rural areas are stunted. In addition, the results show a significant association between breastfeeding and stunting. About 36 per cent of breastfed children are stunted, while approximately 39 per cent of those never breastfed are stunted.

3.3. Results on the spatial distribution of stunting and the effect of mothers' education

The overall prevalence of under-5 stunting is 35 per cent. Fig. 2 presents the distribution of under-5 Stunting prevalence across administrative districts in Sub-Saharan Africa. The map shows spatial variations with higher prevalence of stunting between 35 per cent and 53 per cent in Mali, Ethiopia, Madagascar and Central Africa, predominantly the Democratic Republic of Congo and Angola. More striking is the prevalence of stunting above 53 per cent found in pockets of administrative areas in parts of western Africa, Democratic Republic of Congo, Angola, Tanzania and Madagascar (in the Androy, Amoron'I Mania, Haute Matsiatra, Vakinankraratra, Atsinanana and Analanjirofo). This is consistent with the findings of McKenna et al. (2019), which found that the eastern provinces of the Democratic Republic of Congo, mainly, North-Kivu and South-Kivu have the highest prevalence of stunting in the country. It is also consistent with the World Bank and UNICEF (as cited by Weber, 2017), indicating that Madagascar has one of the highest stunting rates globally, with several areas showing a prevalence above 52 per cent. This was also corroborated by similar studies (Rakotomanana et al., 2017) that found higher rates of stunting above 50 per cent in some regions in Madagascar (Androy, Amoron'I Mania, Haute Matsiatra, Vakinankraratra, Atsinanana and Analanjirofo using WHO data).

Fig. 3 shows the spatial variation of stunting. The overall global moran I is 0.391, indicating that, there is an overall pattern of clustering of stunting. The map shows results on 999 permutations and $p < 0.001$. The result shows statistically significant spatial autocorrelation between administrative areas. Hot spot clusters in red indicate areas with high

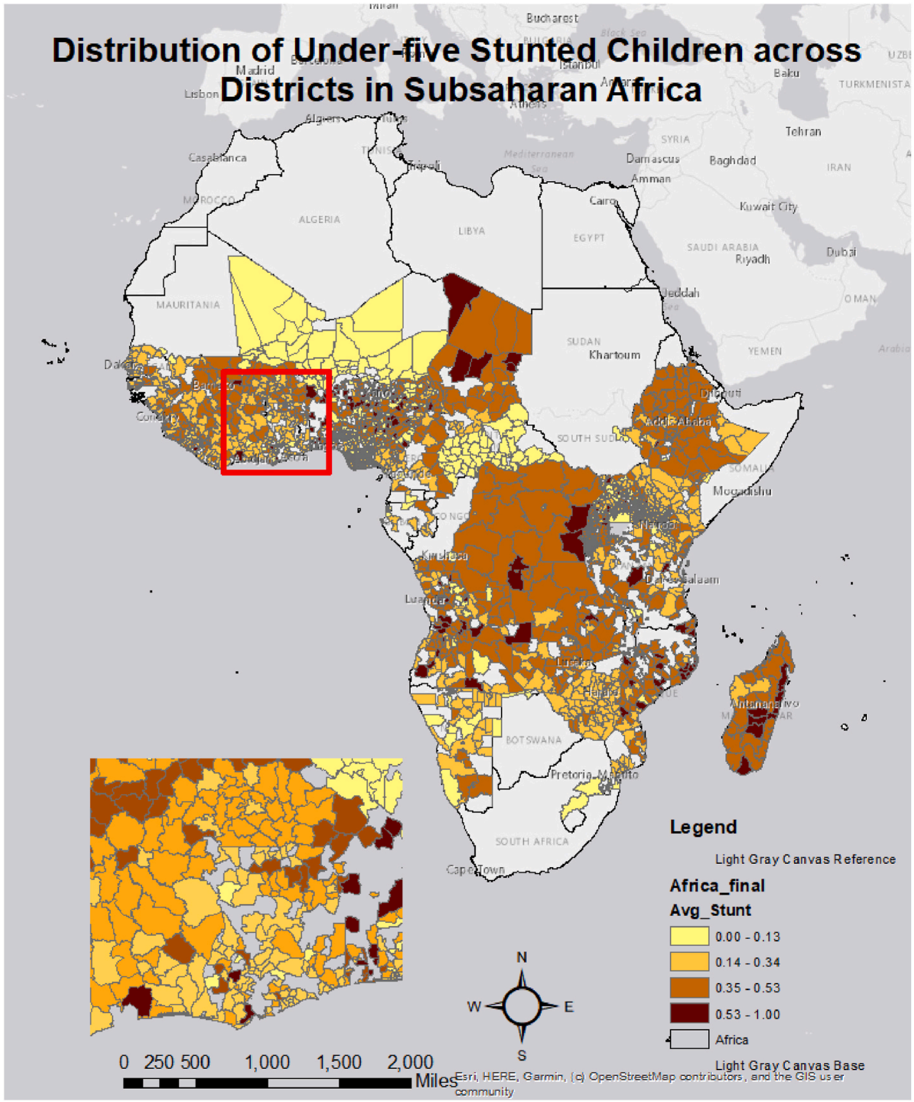

Fig. 2. Distribution of under-five Stunting Prevalence across Administrative Districts in Sub-Saharan Africa.

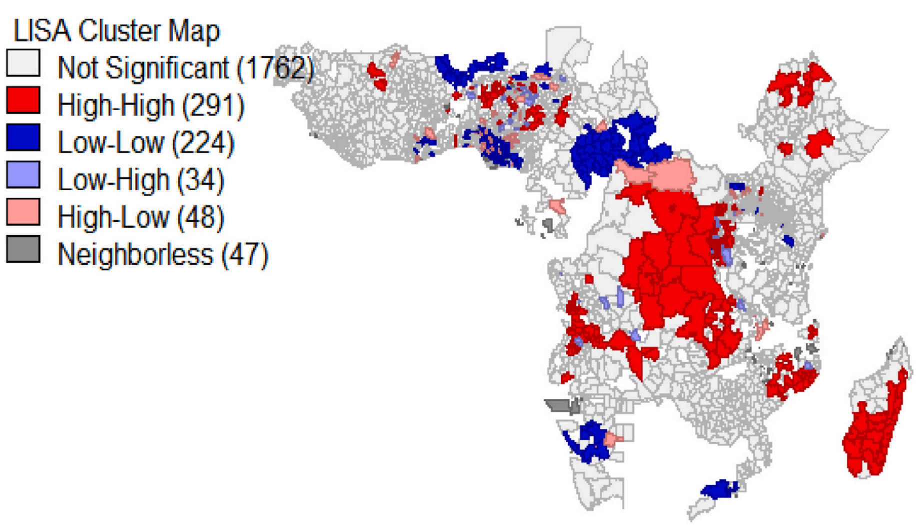

Fig. 3. LISA cluster map of stunting in sub-Saharan Africa.

stunting rates surrounded by equally high stunted areas. The cold spots, however, labelled "low-low", show clusters of lower stunting rates correlating with each other.

Overall, 515 administrative regions show significant clustering of stunting with similar values. 291 are hot spots and 224 are cold spots. The findings corroborate similar studies, which found that residing in some geographic locations adversely affects health outcomes (Adekanmbi et al., 2013; Diez Roux, 2001; Pradhan et al., 2003).

3.4. Neighbourhood effects and effect of neighbouring mothers' education

The risk of an individual child being stunted was regressed on a set of child-level, maternal, household and neighbourhood predictive variables. The study uses multilevel logistic regression to analyse the factors that drive under-5 stunting at the individual and the community/neighbourhood (cluster) levels.

The first model, which is empty and without independent variables, is the null/base model and is presented in Table 4. This shows the extent of community variation on stunting without accounting for any explanatory variable. The result shows a significant variation between neighbourhoods, implying that differences between communities or neighbourhoods can explain the variation in stunting. Appendix 3 provides a caterpillar plot of the neighbourhood effects.

The study adjusted for individual and neighbourhood-level variables in a second model but without a contextual variable of the proportion of educated women in a neighbourhood. This was compared with a logistic model. The results are shown in Table 5. The table also presents two other models with the contextual effect of mothers' education (secondary and higher). Appendix 4 presents the odds ratios for all four models.

From the table, compared to the multilevel models, the standard errors produced by the logistic model underestimate the variability of the coefficient estimates. This is attributed to the fact that logistic regression models, like most traditional regressions, treat observations as independent, so the standard errors of the coefficients would be underestimated in the presence of neighbourhood effect or hierarchical structures (McNeish, 2014). However, the multilevel model (model 2) addresses the issue of dependency between observations in our hierarchical data. Therefore, it is considered more appropriate for this study due to the nature of the research question of modelling variability. The multilevel model reveals that in the presence of a neighbourhood (cluster) effect, a child of a given neighbourhood is correlated with all the children of the same neighbourhood.

Model 3 is an expansion of model 2. It adds the contextual effect of the proportion of mothers with secondary education. The addition of the neighbourhood mothers with secondary education substantially reduces the between-neighbourhood variance from 0.323 to 0.317, implying that the distribution of mothers with secondary education varies across neighbourhoods and contributes to the differences in stunting across neighbourhoods. This is anticipated because some neighbourhoods will have higher proportions of educated mothers than others. Model 4 also shows a reduction of between-neighbourhood variance from 0.323 to 0.320, indicating that the distribution of mothers with higher education contributes to the variations in stunting across neighbourhoods.

Table 4
Base model for the multilevel estimates for stunting.

Base model		
Stunting	Odds ratio	Std. error
Constant	0.498***	0.004
Between neighbourhood variance	0.424***	0.010
Intra-class correlation	0.114	0.002

*p < 0.05; **p < 0.01; ***p < 0.001; Likelihood ratio test statistic = 6832.64 with p-value = 0.000, testing the null that $\sigma^2_{uo} = 0$.

The results show that a child is 45 per cent less likely to be stunted when residing in a neighbourhood where all the mothers have secondary education than another residing in a neighbourhood where none of the mothers have a secondary education. It further shows that a child is 73 per cent less likely to be stunted when living among mothers who have higher education compared to a child residing in a neighbourhood with none of the mothers obtaining higher education (see Appendix 4).

It is evident from the results that children in rural areas are more stunted than those in urban areas. In an attempt to find whether the contextual effect of mothers' education depends on location (thus, varies with residence), mothers' education is interacted with residence. This interaction effect is illustrated graphically in Fig. 4 and presented in Appendix 5. Fig. 4 shows the relationship between the predicted probability of being stunted and residence for neighbourhood proportions of mothers with at least secondary education of 0.1, 0.25, 0.5 and 0.75.

The predicted plot shows that the contextual effect of mothers' education in predicted probabilities for mothers with secondary education is stronger among residents of rural areas. Although a higher proportion of mothers with secondary education in a neighbourhood, irrespective of the residence (rural or urban), reduces a child's probability of being stunted, this effect is stronger for children residing in rural areas than those in urban. More striking is that if the proportion of educated women (at least secondary level) is 75 per cent in both rural and urban areas, the probability of being stunted would be the same irrespective of your residence.

3.5. Other correlates of stunting

In all models (logistic and multilevel logistic models), the study included individual-level characteristics, maternal and neighbourhood-level factors. These consist of child age, sex, birth weight, mother's education level, mother's age, water, sanitation, wealth status, age of household head, household size, residence and breastfeeding. These factors show significant association with childhood stunting, consistent with other empirical works on child health (Annim et al., 2012, 2015; Annim and Imai, 2014; Darteh et al., 2014; Frempong and Annim, 2017; Imai et al., 2012).

All the models show a positive relationship between stunting and the age of the child. Children in higher age groups are more likely to be stunted compared to those below 6 months. This finding is corroborated by earlier works by Annim and Imai (2014) and Darteh et al. (2014). In their study, Annim and Imai found that height-for-age, weight-for-age and weight-for-height z-scores decrease as a child's age increases. The sign and coefficient of the female variable show that female children have a lesser chance of being stunted compared to male children. Specifically, the odds ratio for model 3 indicates that females are 23 per cent less likely to be stunted than males. This finding is consistent with previous works that found that males have a higher probability of being malnourished than females (Bork and Diallo, 2017; Wamani et al., 2007). Another significant variable at the child's level is the child's size at birth. The results indicate that children who are small, average or larger in size at birth are less likely to be stunted than children who are very small in size.

Regarding maternal factors, the models show that children whose mothers have some level of education (primary, secondary and higher) are less likely to be stunted compared to those whose mothers have no education. Another significant maternal factor is the age of the mother. The study found that an additional age of a mother reduces her child's risk of being stunted by 1 per cent. The reason for this association could be that younger women have an immature demeanour to take proper care of their babies' needs, might breastfeed for a shorter duration, may have less education and might not even have a partner (LeGrand and Mbacké, 1993; Wambach and Cole, 2000). Breastfed children are found to have a lesser probability of being stunted than children who have never been breastfed.

The study included household wealth in all the models to understand

Table 5
Estimated coefficients and their associated standard errors of the effect of mothers' education (secondary and higher) on stunting.

	Logistic (1)		Multilevel without contextual effect (2)		Multilevel with contextual effect of mothers' secondary education (3)		Multilevel with contextual effect of mothers' higher education (4)	
Fixed effects: Individual-level	Coeff	Std. error	Coeff	Std. error	Coeff	Std. error	Coeff	Std. error
Child age (Base = below 6)								
6–8	0.215***	0.032	0.218***	0.033	0.219***	0.033	0.219***	0.033
9–11	0.636***	0.030	0.662***	0.031	0.664***	0.031	0.663***	0.031
12–17	1.119***	0.025	1.177***	0.026	1.178***	0.026	1.176***	0.025
18–23	1.637***	0.025	1.741***	0.026	1.743***	0.026	1.741***	0.026
24–35	1.678***	0.023	1.785***	0.023	1.787***	0.023	1.785***	0.023
36–47	1.508***	0.023	1.595***	0.024	1.595***	0.024	1.595***	0.024
48–59	1.250***	0.023	1.318***	0.024	1.319***	0.024	1.318***	0.024
Sex of child (Base = Male)								
Female	−0.248***	0.010	−0.266***	0.010	−0.265***	0.010	−0.266***	0.010
Size at birth (Base = very small)								
Small	−0.022	0.024	−0.098***	0.026	−0.091***	0.026	−0.099***	0.026
Average or Larger	−0.381***	0.020	−0.489***	0.022	−0.482***	0.022	−0.490***	0.022
Mother's education (Base = no education)								
Primary	−0.197***	0.011	−0.169***	0.013	−0.121***	0.014	−0.163***	0.013
Secondary	−0.514***	0.015	−0.454***	0.017	−0.298***	0.020	−0.434***	0.017
Higher	−1.146***	0.045	−1.073***	0.048	−0.890***	0.049	−0.872***	0.050
Mother's age	−0.010***	0.001	−0.011***	0.001	−0.010***	0.001	−0.010***	0.001

Table 5, continued

	(1)		(2)		(3)		(4)	
	Coeff	**Std. error**	**Coeff**	**Std. error**	**Coeff**	**Std. error**	**Coeff**	**Std. error**
Improved water source	−0.116***	0.011	−0.093***	0.013	−0.079***	0.013	−0.089***	0.013
Improved sanitation	−0.124***	0.012	−0.160***	0.014	−0.144***	0.014	−0.155***	0.014
Wealth (Base = poorest)								
Poorer	−0.054***	0.014	−0.084***	0.015	−0.083***	0.015	−0.085***	0.015
Middle	−0.126***	0.015	−0.155***	0.017	−0.152***	0.017	−0.155***	0.017
Richer	−0.231***	0.016	−0.272***	0.019	−0.266***	0.019	−0.269***	0.019
Richest	−0.524***	0.021	−0.558***	0.025	−0.551***	0.025	−0.536***	0.025
Age of head of household	−0.002***	0.000	−0.001+	0.000	−0.001+	0.000	−0.001+	0.000
Ever breastfed (Base = Yes)								
No	0.035	0.033	0.060+	0.035	0.059+	0.035	0.060+	0.035
Intercept	−0.793***	0.039	−0.904***	0.043	−0.820***	0.044	−0.882***	0.043
Contextual Effect: Neighbourhood-level variables								
Residence (Base = urban)								
Rural	0.119***	0.014	0.163***	0.018	0.085***	0.018	0.134***	0.018
Altitude	0.0002***	0.000	0.0002***	0.000	0.0002***	0.000	0.0002***	0.000
Proportion of mothers with secondary/higher levels of education					−0.588***	0.034	−1.295***	0.111
Between neighbourhood variance			0.323***	0.009	0.317***	0.009	0.320***	0.009
Intra-class Correlation			0.089***	0.002	0.089***	0.002	0.089***	0.002
Groups	–		15,470		15,470		15,470	
Observations	204,447		204,447		204,447		204,447	
Log-Likelihood	−123079.34		−121162.2		−121011.09		−121090.35	

*p < 0.05; **p < 0.01; ***p < 0.00.

further the factors that drive child stunting. The results show that children from poorer, middle, richer and richest households are less likely to be stunted than those in poorest households. Children in households with improved water and sanitation are less likely to be stunted than their counterparts from households with unimproved water and sanitation.

4. Discussion

The study presents the rural-urban disparities of child stunting in Sub-Saharan Africa and shows the differences in the effects of neighbourhood mothers' education.

Evidence from 36 developing countries has shown that higher rates of stunting and underweight children relate to residents in rural areas (Smith et al., 2005). Fotso (2006) used multilevel modelling to analyse data from the Demographic and Health Survey (DHS) of 15 Sub-Saharan African countries, concluding that rural-urban differentials are substantially prevalent in all countries.

This study uses data from thirty Sub-Saharan African countries and shows significant rural-urban disparities in stunting to set the premise for a contextual analysis. The descriptive results show that stunting is more prevalent in rural areas than urban areas. This is consistent with WHO's (2015) findings, which state that "even in countries with very low overall prevalence of stunting, disparities are pronounced". It also corroborates previous studies on Ghana (Frempong and Annim, 2017), Bangladesh and Nepal (Srinivasan et al., 2013), and Sub-Saharan African Countries (Takele et al., 2022). The disparities could be attributed to the limited endowment in socioeconomic characteristics and poor quality of infrastructure in rural areas (Srinivasan et al., 2013). The results indicate the significant contribution that studies on stunting inequalities and other child health inequalities would make in the fight against poor health in children. Identifying vulnerable areas and area-specific factors is the first step in designing area-specific health-related policies and strategies to help narrow the gap and address health

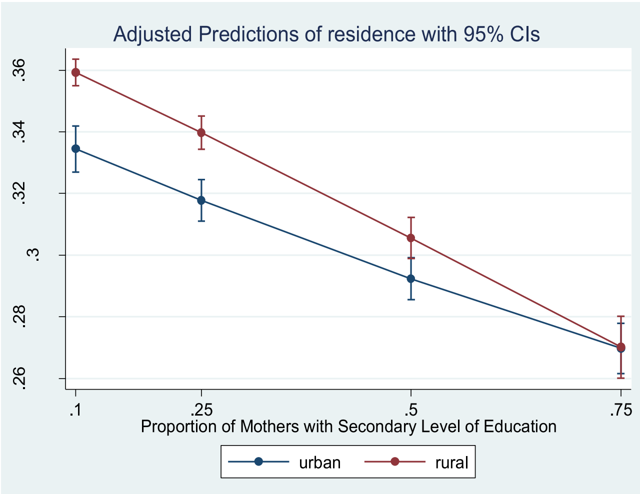

Fig. 4. Predicted probabilities of being stunted by residence and proportion of mothers with secondary education.

inequality problems.

To this end, this study uses a multilevel logistic regression to examine the neighbourhood effects of a key policy variable of stunting, *mothers' education*. First, after adjusting for individual-level characteristics, a comparison between the logistic regression and multilevel logistic regression shows a significant neighbourhood effect. The study demonstrates that higher neighbourhood mothers' education relates to lower stunting outcomes. However, the residential distribution contributes to the variations in stunting across neighbourhoods. Thus, some neighbourhoods have more mothers with secondary or higher education than others. Neighbours with a high educational background can transfer their social and cultural knowledge through the shared social networks that develop within their neighbourhood (Troost et al., 2023). The effect of neighbourhood mothers' education on child stunting can be explained by Pierre Bourdieu's concept of social and cultural capital, as explained by Huang (2019) and Troost et al. (2023), where resource transmission, in this case, valuable information about child health, care, and best practices are obtained through local networks. Mothers living in neighbourhoods with higher neighbourhood mothers' education may gain basic child health-related knowledge through local networks – knowledge sharing and copycatting.

Results of the interaction of neighbourhood mothers' education and residence on stunting indicate that the effect of neighbourhood mothers' education on child stunting is stronger in rural areas than in urban. This finding could be attributed to the fact that social capital networks, which consider connections that enable individuals to relate to each other as argued by Debertin (1996), are quite weak in the urban communities. Residents in rural communities, however, are characterised by a strong willingness in participation and involvement in community activities, similar cultural values and live in close proximity to each other. Hence, though social capital networks may exist in both a rural and an urban community, their relevance may vary significantly. The current study further shows that a target of 75 per cent of mothers' education (at least the secondary education level) in rural and urban communities would help bridge the rural-urban gap of stunting in Sub-Saharan Africa.

The study reiterates the importance of maternal education on child health – which has been extensively researched – premised on Sustainable Development Goals 4 and 5. However, unlike the other studies that have looked at child health and the importance of an individual's own mother's education, this study provides a greater perspective on the importance of women's education by examining neighbouring mothers' education in addition to an individual's own mother's education. The study, thus, extensively positions the importance of women's education, which benefits not just their offspring but also that of children who live close by or in the same community. The findings show further evidence of the effect of mothers' education on childhood stunting and succinctly provide insight into the salience of this association, which is often overlooked in research.

Further research on the differential impact of other determinants of stunting is warranted to understand the neighbourhood effects and differential impacts of these variables on childhood stunting.

5. Conclusion and policy recommendation

The study has shown the eminent rural-urban disparities in stunting from 30 sub-Saharan countries. In most countries, more children in rural areas are stunted than those in urban areas. After adjusting for individual-level factors, the multilevel analysis revealed that the proportion of educated mothers varies across neighbourhoods and contributes to the differences in stunting across residences and neighbourhoods. The effect of mothers' education on stunting in rural areas is greater than in urban areas. This suggests that the gap between the likelihood of a child being stunted in a rural neighbourhood and another child in an urban neighbourhood closes when the proportion of mothers with at least secondary education in the neighbourhood increases. The study highlights the importance of education of women and recommends it as an effective variable to help reduce stunting inequalities in children under 5. From a policy perspective, the study supports interventions that target women's education, especially in rural areas and areas with higher rates of stunting.

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CRediT authorship contribution statement

Vida Afarebea Agyen: Conceptualization, Data curation, Formal analysis, Methodology, Writing - original draft. **Samuel Kobina Annim:** Conceptualization, Supervision, Writing - review & editing. **Emmanuel Ekow Asmah:** Writing - review & editing.

Declaration of competing interest

None declared.

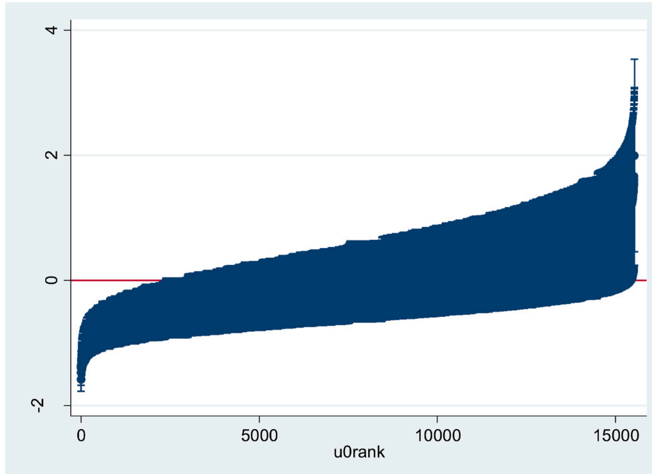
Data availability

Data used is publicly available from the DHS Program (http://dhsprogram.com/)

Appendix 1

Map Showing Sampled Clusters across Countries in Sub-Saharan Africa

Appendix 3. Caterpillar plot of estimated residuals for all the neighbourhood effects



Appendix 2
Under-five malnutrition prevalence by rural-urban residence in sub-Saharan Africa

Malnutrition indicator	Malnutrition Prevalence (%) by residence (rural –urban) for sub-Saharan Africa	
	Rural	Urban
Stunting	78.28 (n = 60,840)	21.72 (n = 16,877)
Wasting	74 (n = 13,785)	25.83 (n = 4801)
Underweight	79.18 (n = 31,862)	20.82 (n = 8379)

Source: DHS >2009

Appendix 4
Estimated odds ratios and their associated standard errors of the effect of mothers' education (secondary and higher) on stunting

	Logistic (1)		Multilevel without contextual effect (2)		Multilevel with contextual effect of mothers' secondary education (3)		Multilevel with contextual effect of mothers' higher education (4)	
Fixed Effects: Individual-level	Odds Ratio	Std. Error	Odds Ratio	Std. Error	Odds Ratio	Std. Error	Odds Ratio	Std. Error
Child age (Base = Below 6)								
6–8	1.240***	0.039	1.244***	0.041	1.245***	0.041	1.245***	0.041
9–11	1.888***	0.057	1.939***	0.061	1.943***	0.061	1.940***	0.061
12–17	3.062***	0.075	3.244***	0.083	3.247***	0.083	3.243***	0.083
18–23	5.138***	0.128	5.706***	0.148	5.717***	0.148	5.706***	0.148
24–35	5.357***	0.121	5.959***	0.140	5.971***	0.140	5.961***	0.140
36–47	4.517***	0.102	4.926***	0.116	4.929***	0.116	4.926***	0.116
48–59	3.489***	0.080	3.734***	0.089	3.738***	0.089	3.734***	0.089
Sex of Child (Base = Male)								
female	0.781***	0.008	0.766***	0.008	0.767***	0.008	0.766***	0.008
Size at birth (Base = very small)								
Small	0.978	0.024	0.906***	0.023	0.913***	0.024	0.906***	0.023
Average or Larger	0.683***	0.014	0.613***	0.013	0.618***	0.013	0.613***	0.013
Mother's education (Base = No Education)								
Primary	0.821***	0.009	0.844***	0.011	0.886***	0.012	0.849***	0.011
Secondary	0.598***	0.009	0.635***	0.011	0.742***	0.015	0.648***	0.011
Higher	0.318***	0.014	0.342***	0.016	0.410***	0.020	0.418***	0.021
mothers_age	0.990***	0.001	0.989***	0.001	0.990***	0.001	0.990***	0.001
Improved water source	0.890***	0.009	0.911***	0.012	0.924***	0.012	0.915***	0.012
Improved Sanitation	0.883***	0.010	0.852***	0.012	0.866***	0.012	0.856***	0.012
Wealth (Base = Poorest)								
Poorer	0.947***	0.013	0.919***	0.014	0.921***	0.014	0.918***	0.014
Middle	0.882***	0.013	0.856***	0.014	0.859***	0.014	0.856***	0.014
Richer	0.794***	0.013	0.762***	0.014	0.766***	0.015	0.764***	0.014
Richest	0.592***	0.013	0.572***	0.014	0.576***	0.014	0.585***	0.014
Age of head of household	0.998***	0.000	0.999^{+}	0.000	0.999	0.000	0.999^{+}	0.000
Ever breastfed (base = Yes)								
No	1.035	0.034	1.062^{+}	0.037	1.061^{+}	0.037	1.062^{+}	0.037

(continued on next page)

Appendix 4 (*continued*)

	Logistic (1)		Multilevel without contextual effect (2)		Multilevel with contextual effect of mothers' secondary education (3)		Multilevel with contextual effect of mothers' higher education (4)	
Fixed Effects: Individual-level	Odds Ratio	Std. Error	Odds Ratio	Std. Error	Odds Ratio	Std. Error	Odds Ratio	Std. Error
Intercept	0.453***	0.018	0.405***	0.018	0.441***	0.019	0.414***	0.018
Contextual Effect: Neighbourhood-level variables								
Residence (Base = Urban)								
Rural	1.127***	0.015	1.176***	0.021	1.089***	0.020	1.144***	0.021
Altitude	1.0002***	0.000	1.0002***	0.000	1.0002***	0.000	1.0002***	0.000
Proportion of mothers with Sec/higher levels of education					0.555***	0.019	0.274***	0.030
Between neighbourhood variance	–		0.323***	0.009	0.317***	0.009	0.320***	0.009
Intra-class Correlation	–		0.089***	0.002	0.088***	0.002	0.089***	0.002
Groups	–		15,470		15,470		15,470	
Observations	204,447		204,447		204,447		204,447	
Log-Likelihood	−123079.34		−121162.2		−121011.09		−121090.4	

Appendix 5
Effect of mothers education dependent on residence

Fixed Effects: Individual-level	Coefficient	Std. Error	Odds Ratio	Std. Error
Child age (Base = Below 6)				
6–8	0.219***	0.033	1.245***	0.041
9–11	0.665***	0.031	1.944***	0.061
12–17	1.178***	0.026	3.248***	0.083
18–23	1.744***	0.026	5.718***	0.148
24–35	1.787***	0.023	5.970***	0.140
36–47	1.595***	0.024	4.930***	0.116
48–59	1.319***	0.024	3.738***	0.089
Sex of child (Base = Male)				
female	−0.265***	0.010	0.767***	0.008
Size at birth (Base = very small)				
Small	−0.091***	0.026	0.913***	0.024
Average or Larger	−0.481***	0.022	0.618***	0.013
Mother's education (Base = No Education)				
Primary	−0.116***	0.014	0.890***	0.012
Secondary	−0.295***	0.020	0.744***	0.015
Higher	−0.899***	0.049	0.407***	0.020
mothers_age	−0.010***	0.001	0.990***	0.001
Improved water source	−0.078***	0.013	0.925***	0.012
Improved Sanitation	−0.144***	0.014	0.866***	0.012
Wealth (Base = Poorest)				
Poorer	−0.081***	0.015	0.922***	0.014
Middle	−0.149***	0.017	0.861***	0.014
Richer	−0.266***	0.019	0.766***	0.015
Richest	−0.554***	0.025	0.574***	0.014
Age of head of household	−0.001	0.000	0.999	0.000
Ever breastfed (base = Yes)				
No	0.059+	0.035	1.061+	0.037
Intercept	−0.871***	0.045	0.414***	0.018
Contextual Effect: Neighbourhood-level variables				
Residence (Base = Urban)				
Rural	0.147***	0.018	1.158***	0.028
Altitude	0.0002***	0.000	1.0002***	0.000
Proportion of mothers with Sec/higher levels of education	−0.471***	0.034	0.624***	0.029
Proportion of mothers with Sec × residence	−0.209***	0.055	0.812***	0.045
Between neighbourhood variance	0.315***	0.009	0.315***	0.009
Intra-class Correlation	0.088***	002	0.088***	0.002
Groups	15,470		15,470	
Observations	204,447		204,447	
Log-Likelihood	−121003.94		−121003.94	

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