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Analysing the drivers of stunting reduction in twelve sub-saharan African countries using the RIF decomposition approach

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Abstract

Background This study examines how significant is the changes in child stunting in Sub-Saharan African countries (SSA). Then, it investigates factors that contributed to the reduction in child stunting in those countries. For each country, we distinguish the contribution of compositional effects and structural effect.

Methods This paper uses data from Demographic and Health Surveys of 12 sub-Saharan African countries conducted between 2000 and 2020. The z-test to compare two independent proportions was used to assess changes in child stunting and explanatory variables over the period. Recentred influence function (RIF) decomposition method was used to decompose changes in stunting over the year in each country, and to determine the contribution of each variable to the changes.

Results The prevalence of child stunting declines significantly in 11 countries over the year. The decline varies from 6.8% in Cameroun to 19% in Mali. The average year of education of the child's mother and father, and the proportion of households with access to an improved drinking water source have contributed to the reduction in child stunting. This result was found in all the countries. Improvements in living standards, child vaccination, antenatal care attendance, delivery to health care centres, maternal education, improved drinking water sources, and improved sanitation make the largest contribution to the composition component, hence reducing child stunting.

Conclusions This study sheds light on what has contributed to the achieved improvement in child nutritional status and suggests how to possibly accelerate the reduction in undernutrition in countries that lag.

Keywords Stunting, RIF decomposition, Sub-saharan African, Reduction

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Background

Child malnutrition is associated with several health problems, poor education performance, and poor productivity in adulthood. It increased morbidity and mortality risks in children. Approximately 45% of deaths of children under five in low- and middle-income countries are due to child and maternal malnutrition [1]. Evidences have shown that undernourished children are at high risk of lowering immune capacity due to a lack of nutrients in their bodies [2]. At the macroeconomic level, child undernutrition has been linked to poor education outcomes [3]. Lack of education could affect adult productivity and income generation [4].

Over the past two decades, several sub-Saharan African (SSA) countries have made considerable progress toward the goal of improving child nutrition. For example, between 2000 and 2020, the prevalence of stunting reduced by at least 10% points [5] in Guinea, Madagascar, Mali, Malawi, Rwanda, Uganda, and Zambia. However, not all SSA countries have experienced a reduction in child stunting. Unfortunately, the prevalence of child malnutrition is still high in SSA countries compared with the rest of the world. In 2019, 52.4 million children in sub-Saharan Africa suffered from chronic malnutrition, compared with 4.7 million in Latin America and the Caribbean.

There is a need to understand what contributed to the reduction of undernutrition in certain SSA countries to formulate policies. These policies could strengthen efforts to end all forms of malnutrition toward the achievement of SDGs[1], and contribute to achieve the African Union's Agenda 2063, which aspires to promote the health and nutrition of the population.

A number of studies report changes in the prevalence of child malnutrition in SSA countries [6, 7]. Changes in child malnutrition may reflect changes in child socioeconomic outcomes. DD Headey [8] reports that the contribution of household socioeconomic status to changes in child stunting varied from 7 to 27% in five of the six developing countries in their study.

When studying changes in malnutrition between two periods, researchers generally consider two sources - the composition effect and the unexplained effect. The composition effects, also known as the explained effect, are attributed to the difference in observable characteristics between the two periods. The unexplained effects, also known as the structural or performance effect, are attributed to the difference in the valuation of observable characteristics in the population between the two periods.

The aim of this study is to examines factors that contributed to the reduction in child stunting in SSA countries. It first identifies which of the effects, component effect or structural effect explains the reduction in child malnutrition in SSA countries. Second, it examines the factors that contribute to component effects. Assessing changes in child nutrition outcomes over time is important for two reasons. First, understanding the evolution and dynamics of the causes of the changes in child malnutrition makes it possible to propose recommendations. Second, this analysis provides an indication of the effect of policies and interventions aimed toward reducing malnutrition.

There is an emerging interest in analysing the factors influencing stunting and evaluating the public policy initiatives that effectively reduce the prevalence of stunting in children. Recent data have shown that key factors accelerating children's nutrition outcomes include maternal education and household socioeconomic status at the individual level and access to healthcare facilities at the community level [9]. In Odisha, parental schooling contributes to a 20% reduction in stunting [10]. Another contributing factor that drives stunting reduction in several settings is the use of healthcare services [8, 11, 12]. LR Buisman, E Van de Poel, O O'Donnell and EK van Doorslaer [11], in a cross-country study in Sub-Saharan Africa, found that the use of healthcare services such as increased iron supplementation during pregnancy, infant immunisation, and deworming contributed to the reduction in stunting in at least four countries.

Majority of the empirical studies focus on explaining the mean difference in the height for age z-score of a child by quantifying the differences due to the gap in the distribution of determinants factors (explained part) of stunting, and the differences attributable to the effects of those factors on stunting (unexplained part) [6, 7, 13]. This paper offers to add to the empirical literature by using a RIF decomposition technique that goes beyond mean decomposition of child stunting. RIF decomposition by Firpo, Fortin, and Lemieux (FFL) [14] is a counterfactual decomposition that explain the contribution of covariates at different quantile of the distribution of the outcome variables.

Methods

Data were from the Demographic and Health Surveys (DHS), which are nationally representative cross-sectional surveys carried out in more than 82 low- and middle-income countries. The DHS uses standardised questionnaires (across countries) to collect health and welfare indicators for women of reproductive age, their children (aged 0–59 months), and their households. Countries were selected based on the availability of at least two surveys rounds, with the first occurring in early 2000 and the second after 2015. In addition, only countries where the prevalence of at least one form of child malnutrition declined significantly by 5% or more were

[1] Sustainable Development Goals.

included. Countries included in this study are Benin (2001, 2017/18), Cameroun (2004, 2018), Guinea (2005, 2018), Madagascar (2003/04, 2021), Mali (2001, 2018), Malawi (2000, 2015/16), Nigeria (2003, 2018), Rwanda (2000, 2019/20), Tanzania (2004/05, 2015/16), Uganda (2000/01, 2016), Zambia (2001, 2018), and Zimbabwe (2005, 2016). The DHS used a multistage stratified sampling design in all countries. Further information on DHS is available at www.dhsprogram.com. For consistency across surveys, only data from children aged 12–35 months were included in this study. The DHS data-collection procedures were approved by the ICF International (Calverton, MD, USA) institutional review board and by the relevant ethical committees in each country.

The outcome variable of the study is Height for age z-score (HAZ) of children aged 12–35 months at the time of the interview. HAZ measures child growth deficiency due to long term cumulative effect of lack of food intake. The child HAZ is calculated by the child's height minus the median height for the child's age and sex in the WHO reference population divided by the standard deviation of this group in the reference population [15]. Children with HAZ values below −2 of the WHO reference population are considered stunted. For the analysis, HAZ (RIF regression) and stunting (descriptive statistics) are used. This study focuses on child stunting outcomes since stunting is relatively stable over the calendar year. Also, stunting contrary to wasting does not depend on the seasonal variation of the context. Indeed, depend on the harvest season (availability of food or not) and weather patterns (related to diseases occurrence), the estimate of the prevalence of wasting in a country may be affected. For example, a child may be affected by wasting more than once in a calendar year due to food shortage or diseases. The survey data can be collected in any given season in a year or spanned across seasons, then the prevalence of wasting of a given survey can be high or low. It is difficult to analyse trend in wasting across surveys as the estimate of the prevalence capture the situation at a specific point in the time and not over the entire year [16].

The variables included in this analysis are identified from the UNICEF nutrition framework [17], and from past studies [18–20]. These are child characteristics such as age and sex, and maternal (education, age at child birth) and household-level factors (socio-economic status). Also, variables are included because, they are collected in each survey round of interest. Covariates used in this analysis include age, immunisation (all routine immunisation for children recommended (BCG, Polio (3 doses), DTP (3 doses), Measle) of the child; the mother's age at birth, education (in years), number of antenatal visits (4+visits vs. <4 visits), place of delivery (health facility vs. other places), preceding birth interval (difference in months between the current birth child and the previous birth); the number of under five children in the household, drinking water source (use of improved drinking water source or not), type of toilet (use of improved toilet facility or not), household wealth index; and father's education (in years). The household wealth index was constructed to account for comparability across countries and survey rounds. Household assets possession (television, radio, phone, fridge, electricity, bicycle, moto, car) and housing characteristics (floor, wall, roof materials) that are available in all rounds for each country were used to construct the wealth index. Principal component analysis was performed on pooled data of the survey rounds of interest for each country.

First, we measure the trend in child stunting and the explanatory variables over time. Second, the z-test for comparing two independent proportions was used to assess the change in child stunting and explanatory variables over time. The changes in the proportion of child stunting and the explanatory variables over time were considered statistically significant if the *p*-value associated with the z-test was less than 0.05. Finally, the quantile decomposition technique proposed by Firpo, Fortin, and Lemieux (FFL) [14] was used to capture the contributing factors to the change in child height-for-age Z-score (HAZ) by combining two rounds of comparative DHS data in each country.

In the literature, the mean-based Oaxaca-Blinder (BO) approach was mostly used to decompose factors that contribute either to change over time or to group gap in child undernutrition prevalence. For instance, MF Sharaf and AS Rashad [13] used BO decomposition to examine the contributing factor of rural/urban gap in child HAZ in Egypt. S Brar, N Akseer, M Sall, K Conway, I Diouf, K Everett, M Islam, PIS Sène, H Tasic and J Wigle [6] examine the variation in the mean of child stunting between two periods (1992/93 to 2017) in Senegal. Since covariate and coefficient contributions may differ at different parts of the distribution of child HAZ, in this study, an extension of Oaxaca-Blinder method that goes beyond mean decomposition of child HAZ is of interest. Because undernourished children are left at the lower tail of HAZ distribution. The study will look at the changes in the distribution of (HAZ) in selected SSA countries between 2000 and 2015. It adds an advantage in explaining how the effect of contributing covariates varies over the conditional distribution of child stunting. This method is quite interesting from the distributional point of view as it allows to see a heterogenous effect of each determinant contributing to the changes in child stunting along different percentiles of the unconditional distribution of the HAZ. P Nie, A Rammohan, W Gwozdz and A Sousa-Poza [21] have used the RIF decomposition by FFl to identify the contributions of household socioeconomic to the changes observed in stunting, underweight and the Composite Index of Anthropometric Failure (CIAF) in India. Similarly to P Nie, A Rammohan, W Gwozdz and A Sousa-Poza [21], this paper uses the RIF decomposition by FFL for the changes analysis.

The recentred influence function (RIF) decomposition by FFL follows a two-stage procedure. In the first stage, the gap between the statistic of interest, let's say the median, is decomposed into the composition effect and coefficient effect.

$$\Delta_{\nu} = \mathrm{v}\left(\mathrm{F}_{\mathrm{Y}}^{0}\right) - \mathrm{v}(\mathrm{F}_{\mathrm{Y}}^{1}) \tag{1}$$

$\mathrm{F}_{\mathrm{Y}}^{\mathrm{i}}$ with i={0,1} is the cumulative distribution function of HAZ in years 0 and 1. Δ_{ν} is the change in the statistic of interest generated by the change in the distribution function of HAZ over the year.

$$\Delta_{\nu} = \left(\mathrm{v}\left(\mathrm{F}_{\mathrm{Y}}^{1}\right) - \mathrm{v}\left(\mathrm{F}_{\mathrm{Y}}^{\mathrm{c}}\right)\right) + \left(\mathrm{v}\left(\mathrm{F}_{\mathrm{Y}}^{\mathrm{c}}\right) - \mathrm{v}\left(\mathrm{F}_{\mathrm{Y}}^{0}\right)\right) \tag{2}$$

$$\Delta_{\mathrm{v}} = \Delta_{\mathrm{S}} + \Delta_{\mathrm{X}} \tag{3}$$

$\mathrm{F}_{\mathrm{Y}}^{\mathrm{c}}$ is a counterfactual distribution of HAZ. Δ_S is the coefficient effect, the gap attributable to the difference in the relationship of Y and X. Δ_X is the composition effect, the gap attributable to the difference in the characteristic X over the year.

In the second stage, the composition and coefficient effects are divided into the contribution of each covariate. The identification of explanatory variables X that contribute to the composition effect and the coefficient effect in explaining the gap in the distributional statistic of interest is obtained by the following decomposition.

$$\Delta_{\mathrm{X}} = (\bar{\mathrm{X}}^{\mathrm{c}\prime} - \bar{\mathrm{X}}^{0\prime})\widehat{\beta}^{0} + \bar{\mathrm{X}}^{\mathrm{c}\prime}(\widehat{\beta}^{\mathrm{c}} - \widehat{\beta}^{0}) \tag{4}$$

$$\Delta_{\mathrm{S}} = \bar{\mathrm{X}}^{1\prime}(\widehat{\beta}^{1} - \widehat{\beta}^{\mathrm{c}}) + (\bar{\mathrm{X}}^{1\prime} - \bar{\mathrm{X}}^{\mathrm{c}\prime})\widehat{\beta}^{\mathrm{c}} \tag{5}$$

Results

Figure 1 shows that between 2000 and 2020, the prevalence of stunting fell significantly in eleven of twelve countries. The prevalence of stunted children declined by more than 15 points between Year 0 and Year 1 in Malawi, Uganda, Zambia, Rwanda, and Mali. In Madagascar, Guinea stunting fell by at least 10 points (annexe Table 1). Stunting reduction in Benin, Cameroon, Nigeria, and Tanzania was less than 10 points between years in consideration. Zimbabwe is the country in which the nutrition status did not fall significantly at 5%.

Table 1 shows the trend in child nutrition status determinants for the eleven countries in which stunting fell significantly. The preceding birth interval, immunisation status of children and proportion of mothers who have attended antenatal care have evolved in the expected direction in some countries. In six countries (Malawi, Uganda, Madagascar, Rwanda, Tanzania, Zambia), the preceding birth interval increased significantly. This increase may reflect family planning policies that encourage the use of modern contraceptives to space births in several Sub-Saharan African countries. The proportion of children who are fully immunised increased significantly by 10% at least in Nigeria, Mali, Tanzania, Rwanda, and Uganda. The proportion of children whose mother has attended at least four antenatal visits increased in Cameroun, Madagascar, Mali, Nigeria, Rwanda, and Uganda. Prior to the new WHO recommendation on the number of prenatal visits, more than four prenatal

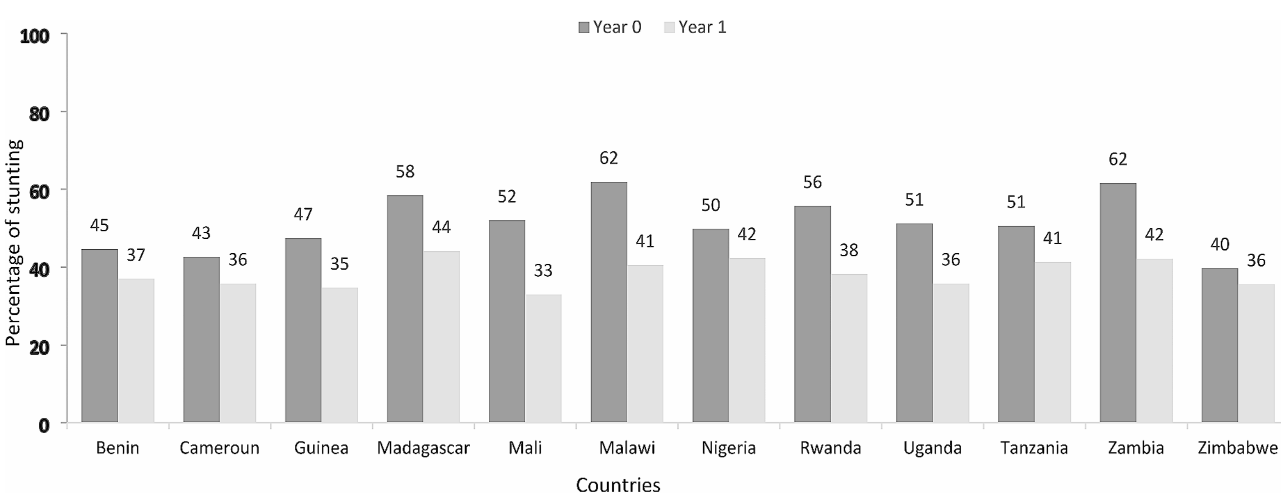

Fig. 1 Change in the prevalence of stunting among children aged 12–35 months. Note: Country (Year0, Year1): Benin (2001, 2017/18), Cameroun (2004, 2018), Guinea (2005, 2018), Madagascar (2003/04, 2021), Mali (2001, 2018), Malawi (2000, 2015/16), Nigeria (2003, 2018), Rwanda (2000, 2019/20), Tanzania (2004/05, 2015/16), Uganda (2000/01, 2016), Zambia (2001, 2018), Zimbabwe (2005, 2016)

Annexe Table 1 Change in the prevalence of stunting among children aged 12–35 months in twelve sub-saharan African countries

	Benin	Cameroun	Guinea	Madagascar	Mali	Malawi	Nigeria	Rwanda	Uganda	Tanzania	Zambia	Zimbabwe
Year0	44.6	42.6	47.4	58.4	52	61.9	49.8	55.7	51.2	50.6	61.6	39.7
N	1615	1313	1034	1722	3628	3888	1686	2229	2173	3009	2315	1580
Year1	37	35.8	34.7	44.1	33	40.5	42.3	38.2	35.8	41.3	42.2	35.6
N	4585	1793	1316	2313	3344	2080	4573	1568	1823	3822	3589	2021
Diff	-7.6*	-6.8*	-12.6*	-14.3*	-19.0*	-21.4*	-7.5*	-17.5*	-15.4*	-9.3*	-19.4*	-4.1¶

HAZ: height for age z score; country (Year0, Year1): Benin (2001, 2017/18), Cameroun (2004, 2018), Guinea (2005, 2018), Madagascar (2003/04, 2021), Mali (2001, 2018), Malawi (2000, 2015/16), Nigeria (2003, 2018), Rwanda (2000, 2019/20), Tanzania (2004/05, 2015/16), Uganda (2000/01, 2016), Zambia (2001, 2018), Zimbabwe (2005, 2016); *, †, and ¶ indicate that changes between years are significantly different from zero at 1%, 5% and 10%, respectively

visits could indicate a critical health status of the mother during pregnancy. In addition, the increase in the number of prenatal visits may be due to what the respondent recalls as prenatal care, as she could count the number of times she visited a health facility during pregnancy, even if the visit was to treat another health problem during pregnancy.

In all countries, the proportion of children born in a health facility has increased significantly. The average year of education of the child's mother and father increased significantly in all countries. The proportion of children in a household with access to an improved drinking water source increased in all countries. This improving trend is observed in access to improved sanitation facilities in all countries, but not in Madagascar, where access to improved facilities has declined over time. The trend in the proportion of households in different wealth quintiles is less clear in all countries. However, the proportion of children in the highest quintile has increased in all countries. Significant improvement in all determinants of children's nutritional status in the expected direction was observed only in Rwanda and Uganda.

Table 1 shows that in Benin, Cameroon, Guinea, Mali, and Nigeria, the interval between births has decreased slightly, and this reduction is only significant in Guinea. The proportion of children with full immunisation significantly decreased in Benin, Guinea, and Madagascar. The proportion of mothers who attended fewer than four antenatal care visits decreased significantly in Benin, Guinea, Malawi, Tanzania, and Zambia.

Quantile decomposition

Figure 2 represents the estimated values of changes and contribution to changes in the first quantile, median and third quantile between two periods for height for age z-score (HAZ) in eleven countries. The decomposition of the total difference in the structure effect and composition effect reveals that the contribution of each component differs by country. Increases in child HAZ across each targeted quantile are mostly attributed to the composition component in Cameroun, Nigeria, and Rwanda. In Benin, Guinea, Madagascar, Mali, Malawi, Uganda, and Zambia the increase in child HAZ across quantiles is greatly attributed to unexplained components.

increase in child HAZ are positive and greater than the unexplained component. In Cameroun, the contribution of the composition component to child HAZ increase varies from 100% at Q75 and 83.3% at Q25 to 73.7% at Q50. In Rwanda and Nigeria, the composition component is counterbalanced by the structural effect in the case of Q25. However, at Q50 and Q75, the composition component contributes to child HAZ increases by 56.8% and 64.7% in Nigeria and by 71.9% and 245.5% in

Rwanda, respectively. The change in the composition of child nutrition determinants over years led to a significant increase in the HAZ across the three quantiles considered in Cameroon, Nigeria, and Rwanda.

In height countries, the unexplained component is positive and greater than the composition component. The change in the distribution of child HAZ over years in those countries is due to the change in the relationship between HAZ and child nutrition determinants. The contribution of the structural effect increases with quantiles in Benin, Guinea, Madagascar, Mali, Malawi, Uganda, and Zambia, except in Tanzania, where the structural effect is counterbalanced by the composition effect in the case of quantile 25%.

Detailed decomposition of the composition component

Table 2 shows the contribution of each child nutrition determinant on the increase in child height for age z-score across year to the composition component at each considered quantile. Table 2 also reveals heterogeneities in the contribution of the determinants across the considered quantile. The changes in the distribution of children with full immunisation significantly contribute to the composition component in Nigeria, Rwanda, and Mali. The increase in the proportion of antenatal care attendance shows a significant contribution to the explained component in Benin, Mali, Rwanda, and Uganda. The increased proportion of delivering in health care centres contributed significantly to the composition component in Mali, Nigeria, Rwanda, and Uganda. The rise in the rates of mothers with at least a year of education significantly contributed to the composition component in Benin, Madagascar, Mali, Malawi, Nigeria, Rwanda, and Uganda. The increased number of children in the highest wealth quintile household contributes significantly to the composition effect in eight countries (Benin, Cameroun, Madagascar, Mali, Malawi, Nigeria, Tanzania, Uganda. The reduction of children in the lowest wealth quintile significantly contributes to the composition component in Benin, Cameroun, Malawi, Nigeria, and Uganda in at least one considered quantile. The change in the proportion of children leaving a household with an improved water source contributes to the composition effect in Mali, Malawi, Uganda, and Zambia. The change in the proportion of children in the household with improved toilet contributes to the composition component in Cameroun, Guinea, Rwanda, and Tanzania.

Discussion and conclusion

This study explored the changes in child height for age z-score (HAZ) in sub-Saharan African countries in the last twenty years using two waves of Demographic and Health Survey data (DHS) in which the first wave was conducted before 2005 and the second wave in 2015 or after. The study assessed how much the change in the national prevalence of stunting between 2000 and 2020 was driven by changes in the distribution of the national population across different determinants of child nutrition (compositional effect) versus changes in the stunting prevalence of each determinant (behavioural effect).

Predominantly, studies analysed the effects of the determinants on the mean change in child HAZ. This study goes beyond the mean and offers a look at the heterogeneous effects of determinants on the difference in the HAZ distribution. In this paper, we used DHS data to conduct a detailed decomposition analysis based on recentred influence function (RIF) regressions. This allows us to identify the sources of the increase in HAZ in each selected country. This study focused on the change in the entire HAZ distribution over time.

The main result of this study is that the changes in child HAZ at various considered quantile points over time are heterogeneous. Across countries, the largest increase in child HAZ is observed in the left tail of the distribution, which suggests that the shift in HAZ distribution was high among children with the lowest HAZ. This result is in line with previous findings by P Nie, A Rammohan, W Gwozdz and A Sousa-Poza [21].

Among the eleven countries included in this study, the composition component mostly explained the change in child HAZ in Cameroon, Nigeria, and Rwanda. The contribution of the composition component is significant and varies across the considered quantiles. In the others nine countries, the structural effects explain the changes in child stunting over time. The differences in the contributing factors of changes in child stunting across countries reflect differences in the social, cultural, economic factors, and the political commitment that influence child feeding practices and health-seeking behaviours [22].

The detailed decomposition shows that improvements in living standards, child vaccination, antenatal care attendance, delivery to health care centres, maternal education, drinking water sources, and sanitation accessibility make the largest contribution to the composition component. The relative importance of these factors varies at different quantiles of the distribution across countries. Improvement in household socioeconomic status (eight countries) and improvement in maternal education (seven countries) emerged from the decomposition analysis as the most important factors associated with an increase in child HAZ.

Maternal education has increased in several SSA in the past years and has played a critical role in improving child growth in this study. The effect of maternal education on the changes in child stunting reflects the lower probability of children with educated mother to be stunted [10, 18, 23]. The positive role of mother with higher education

Table 1 Changes in covariates among children aged 12–35 in sub-saharan African countries

	Benin		Cameroun		Guinea		Madagascar		Mali		Malawi	
	Mean	**Change**	**Mean**	**Change**	**Mean**	**Change**	**Mean**	**Change**	**Mean**	**Change**	**Mean**	**Change**
Child's age in months												
Year 0	23.27		22.54		22.99		22.37		22.74		23.08	
Year 1	23.3	0.03	22.99	0.45¶	21.86	-1.13*	22.93	0.56†	22.56	-0.18	23.26	0.17
Preceding birth interval												
Year 0	38.62		37.12		43.65		38.11		36.85		38.75	
Year 1	38.33	-0.29	36.6	-0.52	40.66	-2.99†	48.01	9.90*	36.58	-0.28	47.17	8.42*
Antenatal visit frequency												
Year 0	63.7		60.8		53		42.2		33.9		58.6	
Year 1	54.4	-9.3%*	66.6	5.8%†	35	-18.0%*	60.7	18.5%*	43	9.1%*	49.7	-8.8%*
Child's Full Immunisation												
Year 0	59.9		50.3		41		55.6		30.3		74.6	
Year 1	55.8	-4.1%†	54.5	4.2%¶	21.6	-19.4%*	49.1	-6.5%†	41.5	11.2%*	74.6	-0.0%
Place of delivery												
Year 0	78.9		59		32.8		32.5		41.2		55.8	
Year 1	86.6	7.7%*	67.5	8.5%*	53	20.2%*	39.2	6.7%*	69.1	27.9%*	94.3	38.5%*
Mother's age at childbirth												
Year 0	26.52		25.42		27.09		26.5		26.77		25.66	
Year 1	26.77	0.26	26.22	0.80*	26.99	-0.10	25.64	-0.86*	26.65	-0.12	25.56	-0.10
Mothers' year of education												
Year 0	1.4		4.56		0.79		3.87		0.91		3.53	
Year 1	2.26	0.86*	5.95	1.39*	2.12	1.33*	4.49	0.62*	1.97	1.07*	5.56	2.04*
Fathers' year of education												
Year 0	2.6		5.49		1.87		4.22		1.52		5.5	
Year 1	3.25	0.65*	6.38	0.89*	3.12	1.25*	4.62	0.40	1.94	0.43*	6.86	1.35*
Number of under 5-year children												
Year 0	2.23		2.19		2.32		1.85		2.2		1.73	
Year 1	2.38	0.15†	2.45	0.26*	2.26	-0.06	1.7	-0.14*	2.26	0.06	1.57	-0.16*
Drinking Water source												
Year 0	45.1		63.2		58.5		27.8		42.1		63.3	
Year 1	67.7	22.6%*	71.5	8.3%*	78.9	20.4%*	41.5	13.7%*	67.6	25.5%*	85.2	21.8%*
Sanitation facilities												
Year 0	15.2		27.5		25.9		46.7		16.1		2.5	
Year 1	28	12.8%*	53.4	25.9%*	47.8	21.8%*	29.4	-17.3%*	53.7	37.6%*	80.2	77.7%*
Quintile==Q1												
Year 0	42.7		48		54.7		32.2		58.5		38.5	
Year 1	28.9	-13.8%*	34.2	-13.8%*	28.9	-25.8%*	36.4	4.2%	19.2	-39.3%*	50.9	12.4%*
Quintile==Q2												
Year 0	35.3		31.8		22.8		44.7		21.7		43.3	

Table 1 (continued)

Year 1	35.3	0.0%	24.9	-6.9%*	28.7	5.9%*	32.5	-12.2%*	32.3	10.6%*	24.5	-18.8%*
Quintile = = Q3												
Year 0	22		20.2		22.4		23.2		19.7		18.2	
Year 1	35.7	13.8%*	40.9	20.7%*	42.4	19.9%*	31.1	7.9%*	48.5	28.7%*	24.6	6.4%*
	Nigeria		**Rwanda**		**Tanzania**		**Uganda**		**Zambia**			
	Mean	**Change**	**Mean**	**Change**	**Mean**	**Change**	**Mean**	**Change**	**Mean**	**Change**		
Child's age in months												
Year 0	22.93		22.8		23.13		22.56		23.02			
Year 1	22.64	-0.29	23.48	0.68*	22.76	-0.37¶	23.26	0.69*	23.23	0.22		
Preceding birth interval												
Year 0	36.58		35.78		39.01		33.55		37.8			
Year 1	37.19	0.61	46.98	11.19*	42.47	3.47*	36.8	3.24*	43.95	6.15*		
Antenatal visit frequency												
Year 0	50		11		66.1		42.7		75.7			
Year 1	62.9	12.9%*	45.1	34.1%*	51.7	-14.5%*	62.3	19.6%*	65.1	-10.6%*		
Child's Full Immunisation												
Year 0	13.7		78.3		31.8		42.5		73.1			
Year 1	32.8	19.0%*	95.5	17.1%*	76.2	44.4%*	57	14.5%*	74.8	1.7%		
Place of delivery												
Year 0	38.2		25.9		47.8		42.4		43.8			
Year 1	49.2	11.0%*	94.1	68.2%*	65.9	18.1%*	75.4	32.9%*	84.5	40.7%*		
Mother's age at childbirth												
Year 0	26.52		28.53		26.18		25.73		25.54			
Year 1	27.71	1.19*	29.36	0.83*	26.79	0.61*	26.27	0.54†	26.42	0.88*		
Mothers' year of education												
Year 0	4.44		3.93		4.89		3.89		5.18			
Year 1	6.44	2.01*	5.39	1.47*	5.72	0.83*	6.11	2.22*	6.43	1.24*		
Fathers' year of education												
Year 0	6.14		4.05		5.79		6.06		7.13			
Year 1	7.86	1.72*	5.43	1.38*	6.33	0.54*	7.25	1.19*	7.55	0.43*		
Number of under 5-year children												
Year 0	2.18		1.8		2.1		2.06		1.93			
Year 1	2.12	-0.06	1.62	-0.18*	2.02	-0.08	1.94	-0.13*	1.77	-0.17*		
Drinking Water source												
Year 0	44.4		42.2		45		0.88		49.3			
Year 1	72.2	27.7%*	78.1	36.0%*	58.7	13.7%*	0.76	-0.12	67.1	17.8%*		
Sanitation facilities												
Year 0	15.5		9.9		3.8		3		15.3			
Year 1	54.2	38.7%*	71.8	62.0%*	27.2	23.4%*	33.7	30.7%*	48.6	33.3%*		
Quintile = = Q1												

Table 1 (continued)

Year 0	37.6		51.7		36.7		40.7		45.1	
Year 1	32.2	-5.3%¶	34	-17.7%*	36.8	0.1%	28.7	-12.0%*	36.3	-8.8%*
Quintile==Q2										
Year 0	31.8		30.8		42.5		41.6		29.1	
Year 1	29	-2.8%	22.7	-8.1%*	23.4	-19.1%*	29.3	-12.2%*	26.7	-2.4%¶
Quintile==Q3										
Year 0	30.7		17.5		20.8		17.7		25.8	
Year 1	38.8	8.1%*	43.3	25.8%*	39.7	19.0%*	42	24.3%*	37	11.2%*

Country (Year0, Year1): Benin (2001, 2017/18), Cameroun (2004, 2018), Guinea (2005, 2018), Madagascar (2003/04, 2021), Mali (2001, 2018), Malawi (2000, 2015/16), Nigeria (2003, 2018), Rwanda (2000, 2019/20), Tanzania (2004/05, 2015/16), Uganda (2000/01, 2016), Zambia (2001, 2018); *, †, and ¶ indicate that changes between years are significantly different from zero at 1%, 5% and 10%, respectively

can be explained through several mechanisms. Previous studies pointed that Women's education is associated with better knowledge about childcaring, healthy behaviour, and factors that reduce the risk of illness [18, 24, 25]. Schooling increases maternal decision power in the household [26] as well as earning potential [27].

Across the majority of countries studied, the result reveals the significant contribution of socioeconomic status to the change in child stunting. Scholars have indicated that the high socio-economic status of a household positively affects the wellbeing of the child [28, 29]. D Asuman, CG Ackah, AP Fenny and F Agyire-Tettey [22] reported that the incidence of stunting is concentrated among children living in households with low socioeconomic status.

Although improvements in living standards have allowed many children to escape malnutrition in the past twenty years, the prevalence of stunting is still at a critical level and remains a major concern for public health in several sub-Saharan African countries. This study sheds light on what has contributed to the achieved improvement in child nutritional status and suggests how to possibly accelerate the reduction in undernutrition in countries that lag behind.

Policymakers need to reinforce policy to promote education, especially girls' education, and to alleviate poverty. Better policies targeted at eradicating child stunting problems should improve nutrition by increasing mothers' education, access to health care, and sanitation in sub-Saharan African countries. Policies should emphasize investment in education, especially for girls, and promote literacy programs for women. Interventions to improve child nutrition should be targeted at vulnerable children in low socio-economic households, through regular monitoring of children in pre-school programs. Community-based management of child malnutrition through household education on food practices and local foods that improve children's nutrition and growth.

This study makes two contributions to the literature. First, the analysis provides the contributing factors of changes in children nutritional status in sub-Saharan African countries over the period 2000–2020. Factors on which to build in order to accelerate progress towards SDG2, which targets the end of all forms of malnutrition by 2030, and contribute to the realisation of the African Union's Agenda 2063, which aspires to promote the health and nutrition of the population. Second, the study employs the FFL decomposition to identify the detail contribution of each factor to the compositional effect.

Some limitations should be taken into account: First, omitted variables may potentially bias the estimates. For instance, environmental factors that may have influenced children's nutritional status were not included in the model due to data availability. Second, it is important

In Cameroun, Rwanda, and Nigeria, the contributions of the composition component to the

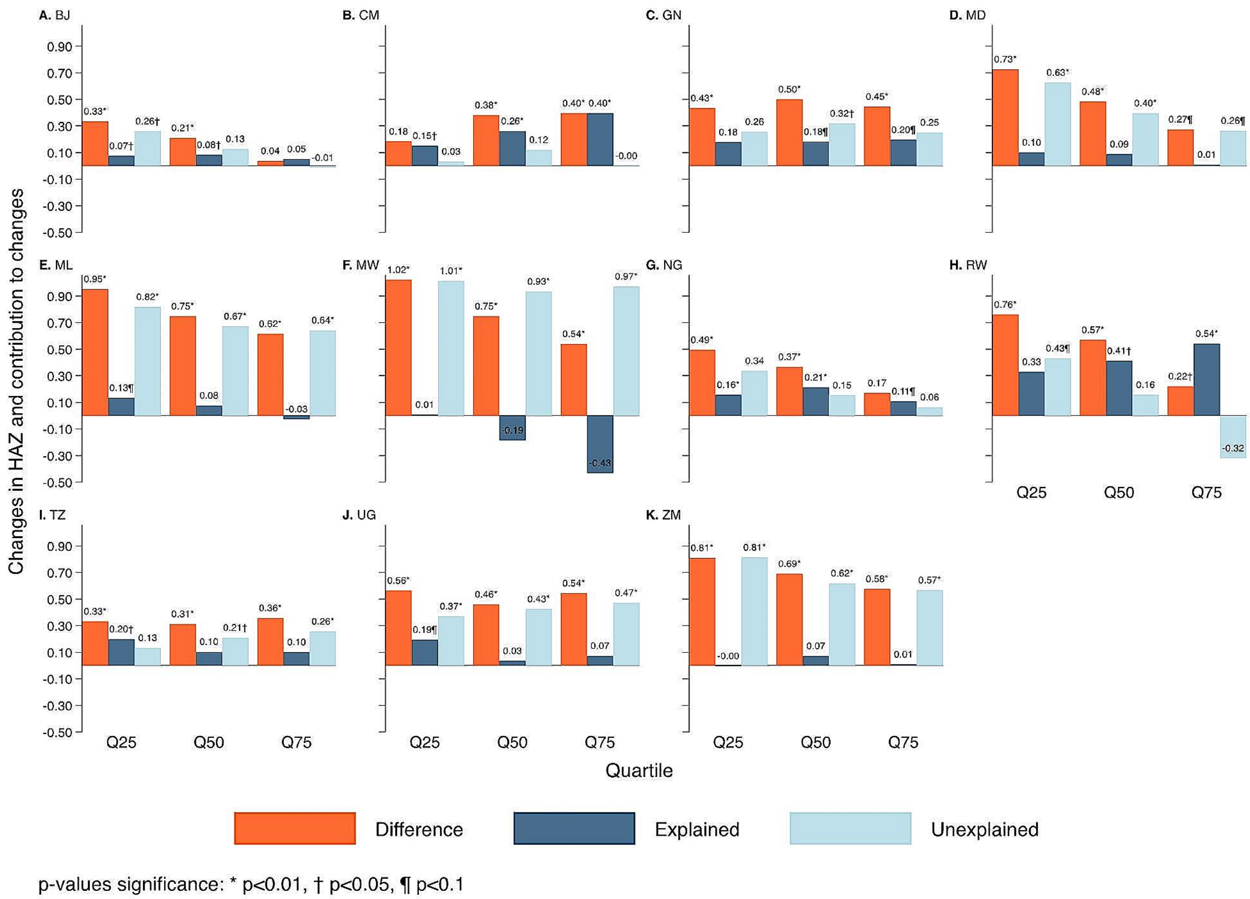

Fig. 2 Total changes, explained, and unexplained effects

to note, however, that while the decomposition analysis has enabled us to identify the sources of increased HAZ between periods within countries, we are not able to attach to them a causal interpretation. RIF decomposition by FFL decompose a difference without assessing causality. Therefore, relating the sources of rising HAZ identified in our analysis to deeper causal interpretation could constitute a priority for future research. Future research is needed to explore the underlying drivers of rural/urban differences in child undernutrition in SSA, it is important to assess spatial-temporal heterogeneities across residence.

Table 2 Detailed decomposition of composition component

	Benin			Cameroun			Guinea			Madagascar			Mali			Malawi		
	Q25	**Q50**	**Q75**	**Q25**	**Q50**	**Q75**	**Q25**	**Q50**	**Q75**	**Q25**	**Q50**	**Q75**	**Q25**	**Q50**	**Q75**	**Q25**	**Q50**	**Q75**
Preceding birth interval	-0.001	0	-0.001	0.008	0.009	0.01	-0.026	0	-0.012	0.014	0.026	-0.008	0.001	0.001	0.001	0.007	0.014	0.02
Child's Full Immunisation	0	0.003	0.005	-0.006	-0.004	0.002	-0.069	-0.042	**-0.089**	0.005	-0.001	0.005	-0.002	-0.006	**-0.021†**	0	-0.002	0.004
Antenatal visit frequency	**-0.019¶**	-0.016	**-0.018¶**	0.027	0.002	0.013	0.002	0.018	0.016	0.02	-0.012	-0.008	**0.011¶**	**0.013¶**	**0.017¶**	0.009	0.009	0.001
Place of delivery	0.003	0.002	-0.009	-0.014	-0.004	-0.002	-0.001	-0.002	0.011	-0.017	0.004	0.017	**0.069†**	**0.058†**	-0.005	0.008	0.017	0.041
Mothers' year of education	**0.011¶**	0.01	0.006	0.02	-0.005	-0.006	0.034	0.038	0.013	-0.007	**-0.015¶**	-0.007	**0.020†**	**0.024†**	0.011	**0.044¶**	0.02	0.008
Mothers' year of education	0	0	0	0.023	0.026	0.007	-0.01	-0.001	-0.003	0	0.001	0.006	0	0.001	0.005	-0.002	0.002	-0.001
Drinking Water source	0.029	0.016	0.02	-0.014	-0.019	0.007	-0.022	-0.003	0.063	-0.005	-0.026	-0.031	0.042	**0.044¶**	0.037	0.003	-0.014	**-0.034¶**
Sanitation facilities	-0.007	0	0.012	0.026	**0.136¶**	0.059	0.078	**0.077¶**	0.048	-0.01	0.001	0.02	-0.007	0.012	0.009	0.054	**-0.084**	0.078
Quintile==Q1	**0.028***	**0.024***	**0.018†**	0.015	**0.046†**	**0.051†**	0.037	0.034	0.027	0.002	0.001	0.002	0.014	0	-0.019	**-0.020†**	**-0.015¶**	**-0.036***
Quintile==Q2	-0.002	0	-0.001	**0.022¶**	**0.018¶**	**0.029***	-0.005	-0.003	-0.003	**0.016¶**	**0.025†**	0.011	-0.009	**-0.017†**	**-0.019†**	0.003	0.003	0.002
Quintile==Q3	**0.028†**	**0.032***	**0.019¶**	**0.092†**	**0.125***	**0.167***	0.049	0.039	0.032	**0.032***	**0.038***	**0.025¶**	0.031	**0.040†**	0.032	**-0.045†**	**-0.046†**	**-0.052†**
Number of under 5-year children	**0.007¶**	**0.007¶**	0.004	0.003	-0.001	0.001	-0.001	-0.002	-0.002	**0.031¶**	0.028	**0.030¶**	0.001	-0.003	0	0.008	-0.003	0
Child's age in months	-0.002	-0.002	-0.002	-0.009	-0.006	-0.008	-0.011	-0.016	-0.018	0	-0.001	-0.001	**-0.014¶**	**-0.013¶**	**-0.016¶**	0.006	0.009	0.011
Mother's age at childbirth	0.001	0.002	0.001	0.002	0.001	0.002	0	0.005	0.013	-0.002	-0.006	0.003	0	0	-0.001	-0.003	-0.004	-0.004
				Nigeria			**Rwanda**			**Tanzania**			**Uganda**			**Zambia**		
				Q25	**Q50**	**Q75**	**Q25**	**Q50**	**Q75**	**Q25**	**Q50**	**Q75**	**Q25**	**Q50**	**Q75**	**Q25**	**Q50**	**Q75**
Preceding birth interval				0.004	0.001	0.003	0.016	0.003	0.002	0.009	0.013	0.009	**0.022†**	0.012	**0.025†**	0.02	0.007	0.008
Child's Full Immunisation				**0.053¶**	**0.057†**	**0.072†**	-0.058	**-0.096¶**	**-0.097**	0.087	0.025	-0.015	-0.011	-0.007	-0.018	0	-0.008	-0.007
Antenatal visit frequency				-0.001	0.014	0.009	**0.123***	**0.121***	**0.083†**	-0.021	**-0.023¶**	**-0.024¶**	0.032	0.006	0.017	-0.006	0.008	-0.003
Place of delivery				**0.026¶**	**0.037†**	**0.051***	0.056	**0.488***	**0.294***	0.007	0.01	0.007	**-0.085†**	-0.066	-0.075	-0.005	0.031	0.052
Mothers' year of education				**0.054***	**0.043†**	0.016	**0.096†**	0.029	0.017	0.007	0.003	-0.003	**0.049¶**	**0.061†**	0.016	0.004	0.004	0.002
Mothers' year of education				**0.028†**	0.009	0.009	0.008	0.015	-0.002	-0.005	-0.004	-0.004	-0.007	-0.008	0	0.003	-0.007	-0.005
Drinking Water source				-0.028	-0.003	-0.033	-0.002	-0.021	0.001	0.01	-0.002	0.006	**0.025†**	**0.025†**	0.012	**0.041†**	**0.039†**	**0.033¶**
Sanitation facilities				0.019	-0.052	-0.073	**0.129†**	**0.163***	**0.191***	0.041	**0.056¶**	**0.063¶**	-0.035	0.019	0.019	-0.04	0.01	0.025
Quintile==Q1				0.007	0.009	**0.008¶**	0.006	0.005	0.005	0.004	0.004	0.003	**0.021†**	**0.013¶**	**0.014¶**	0.002	-0.001	0.002
Quintile==Q2				0.001	0.001	0	0.002	-0.002	-0.004	0.006	0.014	**0.022†**	-0.001	-0.001	0.005	0.001	0.001	0.001
Quintile==Q3				0.012	**0.016†**	0.008	-0.003	-0.004	-0.004	**0.027†**	**0.036†**	**0.040***	**0.046***	0.029	**0.042†**	0	-0.002	0
Number of under 5-year children				0.007	0.006	0.006	0.04	0.018	0.007	-0.004	-0.007	0.004	0.001	-0.001	0.003	0.001	0.011	0.014
Child's age in months				**0.019†**	**0.015†**	**0.012†**	-0.04	-0.011	-0.027	-0.002	-0.002	-0.003	0	0	0	-0.003	0.004	0.007
Mother's age at childbirth				0	0	0	0	0	0.001	0.003	-0.001	-0.004	0	0	0	0	0.001	0.001

*, †, and ¶ indicate that the coefficient is significantly different from zero at 1%, 5%, and 10%, respectively

Abbreviations

SSA Sub-Saharan African
HAZ Height for age z-score
RIF Recentred influence function

Author contributions

AAO wrote the main manuscript AAO prepares data curation and formal analysis.

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Data availability

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Ethics approval and consent to participate

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Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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