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Inequality Trends in Childhood Anemia across Ethiopian Regions: Evidence from DHS 2005–2016

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Abstract

Anemia remains one of the most widespread nutritional disorders among young children globally. In 2019 alone, nearly 270 million children aged 6–59 months were affected, with African countries bearing a disproportionate share of the burden. Ethiopia continues to face a high prevalence of childhood anemia, characterized by marked differences across administrative regions. Understanding how these regional disparities have evolved over time is essential for guiding equitable public health interventions. This study investigates changes in regional inequality in childhood anemia in Ethiopia between 2005 and 2016.Data for this study were obtained from three nationally representative Ethiopian Demographic and Health Surveys conducted in 2005, 2011, and 2016. The analysis included 17,766 children aged 6–59 months. To account for the hierarchical structure of the data, multilevel binary logistic regression models were fitted to examine factors associated with childhood anemia at individual, household, and community levels. Regional inequality and its temporal changes were assessed using the Theil index, while multivariate decomposition techniques were applied to distinguish the contributions of compositional and structural factors. The likelihood of childhood anemia was influenced by a combination of characteristics operating across multiple levels of analysis ($p < 0.001$). Considerable regional variation was observed throughout the study period, with the Somali and Afar regions consistently exhibiting the highest anemia prevalence, whereas Amhara, Addis Ababa, and the Southern Nations, Nationalities, and Peoples' Region recorded comparatively lower levels. The overall measure of relative regional inequality declined modestly, from 0.620 in 2005 to 0.548 in 2016. Decomposition results indicated that roughly one-third of the observed reduction in inequality was explained by differences in measurable population characteristics across regions. Despite some improvement, progress in reducing regional disparities in childhood anemia in Ethiopia has been limited. Over the 11-year period, relative inequality declined by just over 13%, indicating persistent gaps between regions. Addressing inequities related to socioeconomic conditions, maternal anemia, and maternal labor participation—particularly between emerging and more developed regions—remains critical for achieving meaningful reductions in childhood anemia and promoting health equity.

Keywords: Anemia, Childhood anemia, Nutritional disorders, Health equity

Introduction

Anemia is a condition defined by a reduced concentration of red blood cells or hemoglobin (Hb) below established normal thresholds [1], and it is widely used as a key indicator of child survival [2]. Children under the age of five experience a substantially higher burden of anemia compared with the general population [3]. Among children aged 6–59 months, anemia is identified when hemoglobin levels fall below 110 g/l [1], making it one of the most critical public health problems in low- and middle-income countries [4]. Childhood anemia is associated with adverse outcomes, including stunted physical growth, compromised cognitive development and learning performance [5], and elevated risks of illness and death [6].

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In 2019, an estimated 269 million children aged 6–59 months were affected by anemia worldwide, with approximately 103 million of these cases occurring in Africa [7]. Sub-Saharan Africa (SSA) continues to bear the greatest share of the global childhood anemia burden [8], where over 64% of children under five were anemic in 2019 [9]. As a result, childhood anemia remains a major public health challenge throughout SSA, including Ethiopia [10]. Although Ethiopia has demonstrated sustained commitment to implementing nutrition-related programs and policies since 2008 [9-11], anemia among young children persists as a significant national health concern.

Marked disparities in childhood anemia prevalence are evident across Ethiopia's administrative regions. In 2016, the Somali region reported the highest prevalence (83%), followed by the Afar region (75%), while the Amhara region exhibited the lowest prevalence (42%) [12]. Previous studies have consistently documented geographic inequalities in childhood anemia within the country [13-16]. In addition to regional differences, childhood anemia has worsened at the national level, increasing from 54% in 2005 to 57% in 2016 among children aged 6–59 months [12]. These trends highlight the urgent need for systematic, evidence-based assessments of how regional inequalities in childhood anemia have evolved over time. Such analyses are essential for monitoring existing interventions and informing context-specific policy responses at the regional level. Furthermore, understanding temporal changes in regional disparities can support policymakers and regional authorities in revisiting and refining child health strategies.

While many studies [12-15] have examined inequalities and trends in childhood anemia, only a small number of investigations [17-20] have explicitly focused on regional disparities in developing-country settings. Moreover, most prior research did not account for the hierarchical nature of population-based survey data when identifying determinants of childhood anemia and rarely employed multilevel analytical approaches to assess the influence of individual, household, and community factors simultaneously. In addition, earlier studies did not quantify the respective contributions of observed and unobserved heterogeneity across these levels using decomposition techniques. To our knowledge, no study in Ethiopia has combined multilevel modeling, decomposition analysis, and Theil Index measures to evaluate trends in regional inequalities in childhood anemia. This study therefore seeks to fill this methodological gap by addressing the question: **"**How have regional disparities in childhood anemia in Ethiopia changed between 2005 and 2016?**"**

Materials and Methods

Study setting

Ethiopia features significant ethnic and geographic diversity [21]. As a landlocked nation, it shares borders with Eritrea in the north and northeast, Djibouti in the east, Somalia in the southeast and east, Kenya in the south, and Sudan along with South Sudan in the west [22]. From 2000 to 2015, the country pursued the Millennium Development Goals (MDGs) and made substantial gains in reducing child mortality. The government of Ethiopia has shown firm dedication to integrating the Sustainable Development Goals (SDGs) and the 2030 Agenda into its core national planning structures [17]. Following this, the Growth and Transformation Plan II (GTP II), aligned with the SDGs, was adopted and executed by every regional state and city administration [17]. Despite economic growth observed between 2005 and 2016, regional states displayed considerable variation in achievements related to non-monetary welfare and poverty alleviation [18]. Notably, drought-prone and pastoralist areas such as Afar and Somali regions performed poorly across all non-monetary metrics, even though consumption-based regional inequality remained modest [19]. Across regions, both the Gini coefficient for overall inequality and children's inequality of opportunity exhibited wide differences [18].

Data source

Data for this research came from three waves of the Ethiopian Demographic and Health Surveys (EDHSs) spanning 2005 to 2016. Employing cross-sectional designs, these nationally representative surveys aimed to assess and monitor key indicators of child and maternal health, among them anemia. Selection of households and enumeration areas relied on a two-stage stratified cluster sampling method [12]. Information collected in the EDHSs covered household and individual attributes related to nutrition, health, demographics, socioeconomic status, and geography, with interviews targeting women between 15 and 49 years of age. Merging datasets from all three survey rounds yielded a combined analytic sample of 17,766 children between 6 and 59 months old.

Study variables

- *Outcome variable*

The primary outcome of interest was childhood anemia. This variable was coded as binary, taking a value of 1 for children classified as having mild, moderate, or severe anemia, and a value of 0 for children with normal hemoglobin levels (non-anemic).

- *Explanatory variables*

The independent variables included in this study were categorized into an exposure variable and a set of covariates. Administrative region, measured at the community level, was treated as the main exposure variable and considered a central driver of inequality in childhood anemia [15]. Ethiopia's eleven administrative regions were included and subsequently regrouped into three broader regional classifications for analytical purposes: established regions (Oromia, Amhara, Southern Nations, Harari, Tigray and Nationalities and Peoples' Region (SNNPR)), emerging regions (Somali, Afar, Gambella and Benishangul-Gumuz), and fully urban regions (Addis Ababa and Dire Dawa City Administrations) [20]. For the decomposition analysis, this classification was further simplified into a binary regional category distinguishing emerging regions from non-emerging regions (which combined established and urban areas).

The selection of covariates was informed by UNICEF's conceptual framework on child malnutrition [23] and the Mosley and Chen framework for child survival [24]. Accordingly, covariates were organized into community-, household-, and individual-level factors. At the community level, place of residence was included and classified as either urban or rural.

Household-level covariates comprised sex of the household head (male or female), household size (fewer than six members or six and above), number of children under five in the household (fewer than two or two and above), and household wealth status. The wealth index was initially categorized into five quintiles (poorest, poorer, middle, richer, and richest) and later regrouped into poor (poorest and poorer) and non-poor (middle, richer, and richest) households.

Individual-level variables included child sex (male/female), age of the child in months (6–23 or 24–59 months), perceived size at birth as reported by the mother (small, average, or large), birth order (first, second–fourth, or fifth and above), and child nutritional status (undernourished or nourished). Additional variables captured breastfeeding duration (never breastfed, up to 12 months, or more than 12 months), maternal educational attainment (no formal education, primary, or secondary and above), partner's educational level (no formal education, primary, or secondary and above), maternal employment status (employed or not employed), maternal anemia status (anemic or non-anemic), maternal age at childbirth calculated from the mother's and child's dates of birth (younger than 19 years or 19 years and above), place of delivery (home or health facility), and survey period (2005–2011 or 2012–2016).

Statistical methods

All analyses were conducted using STATA version 17.0 (College Station, Texas 77845, USA). Observations with missing anthropometric measurements (weight, height/length) or other incomplete responses were excluded from the analysis. Descriptive statistical techniques were applied to summarize the characteristics of the study population. Multicollinearity among explanatory variables was assessed using the Variance Inflation Factor (VIF), applying a cutoff value of 2.5 [25], with detailed results provided in Annex 1.

Bivariate analyses were first performed to examine crude associations between each explanatory variable and childhood anemia. Variables demonstrating associations at a significance level of $p < 0.2$ were retained as candidates for inclusion in the multilevel regression models.

To estimate adjusted associations, a multilevel binary logistic regression model with mixed effects was employed [26]. This approach accounts for the hierarchical nature of the EDHS data, in which children are nested within households, and households are nested within communities or enumeration areas (EAs). Conventional regression techniques are inappropriate for such clustered data structures, as they may yield biased parameter estimates [27]. A three-level modeling framework was therefore specified, with individual-, household-, and community-level variables corresponding to levels one, two, and three, respectively. Model building proceeded sequentially. An empty (null) model was first fitted to assess the necessity of multilevel modeling. Model I included community-level predictors (administrative region and place of residence) while controlling for lower-level variables. Household-level covariates were added in Model II, and the final specification (Model III) incorporated community-, household-, and individual-level predictors simultaneously to evaluate their independent effects on childhood anemia. Model performance and goodness-of-fit were assessed using the Intraclass Correlation Coefficient (ICC), Median Odds Ratio (MOR), Likelihood Ratio (LR) test, and information criteria (AIC and BIC) [28].

Regional inequalities in childhood anemia were quantified using the Theil Index [29], which allows decomposition into within-region and between-region components [30]. Survey period was incorporated to examine temporal changes in relative regional inequality [31]. In addition, multivariate decomposition analysis was applied to estimate the relative contributions of different factors to inequalities between regional categories [32]. All statistical analyses were performed using survey-weighted data to ensure national representativeness.

Results and Discussion

Characteristics of the study population

Table 1 presents the distribution of children aged 6–59 months by key regional, household, and individual characteristics. Slightly more than half of the children included in the analysis (54.54%) were drawn from established regions. Children from emerging regions constituted approximately 37% of the sample, while those residing in the two chartered city administrations—classified as urban regions—accounted for just over 8%. A predominantly rural population was observed, with 84.95% of children living outside urban areas.

Socioeconomic conditions varied modestly across households. Children from economically disadvantaged households represented 50.38% of the sample, marginally exceeding those from non-poor households (49.62%). Most children lived in households headed by males (83.25%), whereas female-headed households accounted for 16.75%. Large household size was common: 57.10% of children resided in households with six or more members, and roughly two-thirds of households reported having more than two children under five years of age during the survey period.

With respect to child-level characteristics, females comprised a slightly higher proportion of the sample (50.97%) than males (49.03%). Children aged 24–59 months made up more than 67% of the study population. Home delivery was the predominant mode of childbirth, reported for 81.53% of children, while only 18.47% were delivered in health facilities. First-born children accounted for a relatively small share (17.92%) of the sample. Nutritional assessment indicated that 52.51% of children were undernourished.

Breastfeeding practices showed considerable variation. More than half of the children (57.31%) were breastfed for longer than 12 months, whereas 2.66% had never been breastfed. Early maternal age at childbirth was reported for about 9% of children, whose mothers were younger than 19 years at the time of delivery. Educational attainment among mothers was generally low, with 69.65% having no formal education; only 30.35% had completed at least primary education. Similarly, nearly 53% of children had fathers or partners with no formal schooling.

Maternal health and employment indicators revealed that 70.86% of children were born to mothers who were anemic. In addition, 57.69% of children had mothers who were not engaged in paid employment. Regarding survey timing, the majority of observations (approximately 61%) were obtained from the earlier survey rounds conducted between 2005 and 2011 **(Table 1).**

Table 1. Background characteristics of the study participants, Ethiopia, 2005–2016

Category	Sub-category	%	N
Household-level factors			
Sex of household head	Female	16.75	2,976
	Male	83.25	14,790
Wealth status	Poor	50.38	8,950
	Non-poor	49.62	8,816
Number of under-five children in the household	< 2	33.81	6,007
	2 or more	66.19	11,759
Household size	< 6 members	42.90	7,622
	6 or more members	57.10	10,144

Individual-level drivers			
Age of child (months)	6–23 months	32.59	5,790
	24–59 months	67.41	11,976
Place of delivery	Home	81.53	14,485
	Health facility	18.47	3,281
Sex of child	Male	49.03	8,711
	Female	50.97	9,055
Child size at birth	Large	30.27	5,353
	Average	41.43	7,327
	Small	28.31	5,007
Duration of breastfeeding	Never breastfed	2.66	472
	< 12 months	40.03	7,112
	12 or more months	57.31	10,182
Birth order	First	17.92	3,183
	2nd to 4th	44.78	7,955
	5th and above	37.31	6,628
Maternal age at childbirth	< 19 years	8.93	1,587
	19 years or older	91.07	16,179
Maternal education	No education	69.65	12,374
	Primary or higher	30.35	5,392
Partner's education	No education	52.35	9,301
	Primary or higher	47.65	8,465
Nutrition status	Nourished	47.49	8,437
	Undernourished*	52.51	9,329
Maternal employment	No	57.69	10,249
	Yes	42.31	7,517
Survey period	2005–2011	61.37	10,903
	2012–2016	38.63	6,863
Maternal anemia	Not anemic	70.86	12,589
	Anemic	29.14	5,177
Community-level drivers			
Place of residence	Rural	84.95	15,092
	Urban	15.05	2,674
Regional category	Established	54.54	9,690
	Emerging	37.00	6,573
	Urban	8.46	1,503

*Undernourished refers to wasting, stunting and underweight
Source: Authors analysis using EDHS 2005–2016

Bivariate analysis results

Table 2 displays the crude associations between childhood anemia and the selected explanatory variables. When data from all three survey rounds were pooled, childhood anemia affected 54.77% of children nationally between 2005 and 2016. A clear difference was evident across survey periods: anemia prevalence was substantially higher in the more recent surveys (2012–2016), where 60.47% of children were anemic, compared with the earlier period (2005–2011), and this difference was statistically significant ($p < 0.001$).

Analysis at the community level indicated that childhood anemia varied significantly according to regional grouping and urban–rural residence ($p < 0.001$). Household characteristics were also strongly related to anemia status. Significant associations ($p < 0.001$) were observed for household wealth status, sex of the household head, total household size, and the number of children under five living in the household.

At the individual level, multiple maternal and child characteristics demonstrated statistically significant relationships with childhood anemia ($p < 0.001$). These included maternal educational level, maternal anemia status, maternal employment status, partner's educational attainment, place of delivery, child nutritional status, child age category, and maternal assessment of the child's size at birth. Conversely, no meaningful association was detected between childhood anemia and either the sex of the child or maternal age at the time of childbirth at the predetermined screening level ($p < 0.2$).

Table 2. Bivariate analysis of explanatory variables by childhood anemia, Ethiopia, 2005–2016

Explanatory Variables	Chi-square	Not Anemic %	Not Anemic N	Anemic %	Anemic N
Community level drivers					
Regional Category	397.31***				
Established		51.86	5025	48.14	4665
Emerging		36.12	2374	63.88	4199
Urban		42.32	636	57.68	867
Number of under-five in the HH	102.17***				
2 +		42.53	5001	57.47	6758
< 2		50.51	3034	49.49	2973
Sex of household head	11.48***				
Female		42.41	1262	57.59	1714
Male		45.79	6773	54.21	8017
Individual level drivers					
Sex of child	0.49				
Male		45.49	3963	54.51	4748
Female		44.97	4072	55.03	4983
Age of child in months	802.10***				
24–59 months		52.58	6297	47.42	5679
6–23 months		30.02	1738	69.98	4052
Place of delivery	3.79*				
Health facility		46.75	1534	53.25	1747
Home		44.88	6501	55.12	7984
Place of residence	43.01***				
Urban		51.05	1365	48.95	1309
Rural		44.20	6670	55.80	8422
Household level drivers					
Wealth status	239.95***				
Non-poor		51.05	4501	48.95	4315
Poor		39.49	3534	60.51	5416
Household size	10.78***				
6 +		44.16	4480	55.84	5664
< 6		46.64	3555	53.36	4067
Nutritional status of child	117.57***				
Undernourished		41.40	3860	58.60	5469
Nourished		49.55	4175	50.45	4262
Child size at birth	43.80***				
Large		46.46	2487	53.54	2866
Average		46.98	3442	53.02	3885
Small		41.28	2067	58.72	2940
Birth order	31.09***				
First order		48.82	1554	51.18	1629
2nd to 4th order		45.68	3634	54.32	4321
Duration of breastfeeding	324.51***				
Never breast feed		45.97	217	54.03	255
Fifth and above		42.95	2847	57.05	3781
12 + months		50.90	5183	49.10	4999
< 12 months		37.05	2635	62.95	4477
Maternal education	52.20***				
Primary +		49.31	2659	50.69	2733
No education		43.45	5376	56.55	6998
Maternal Employment	240.51***				
No		40.27	4127	59.73	6122

Yes		51.99	3908	48.01	3609
Age at child birth	0.49				
< 19		46.06	731	53.94	856
19 +		45.14	7304	54.86	8875
Partner's education	73.24***				
No education		42.18	3923	57.82	5378
Primary +		48.58	4112	51.42	4353
Survey period	146.47***				
2005–2011		48.81	5322	51.19	5581
2012–2016		39.53	2713	60.47	4150
Maternal anemia	418.09***				
Not anemic		50.12	6310	49.88	6279
Anemic		33.32	1725	66.68	3452
Total		45.23	8035	54.77	9731

*p < 0.1, **p < 0.05, ***p < 0.01

Source: Authors analysis using EDHS 2005–2016

Multilevel analysis findings

The results from the multilevel binary logistic regression models identifying factors associated with childhood anemia are summarized in **Table 3**. The empty (null) model was statistically significant, confirming the presence of meaningful clustering in the data and justifying the application of a multilevel analytical approach.

In the first adjusted model (Model I), which included community-level predictors, pronounced regional differences were observed. Children living in emerging regions exhibited a significantly higher probability of being anemic compared with those residing in established regions (p < 0.001). In addition, place of residence showed a strong association with childhood anemia, with children from urban settings having a substantially lower likelihood of anemia than their rural counterparts (p < 0.001).

Table 3. Results of multilevel logistic regression analysis (N = 17,766), Ethiopia, EDHS 2005–2016

Explanatory Variables	Model III Coef. [95% CI]	Model II Coef. [95% CI]	Model I Coef. [95% CI]	Model 0 Coef. [95% CI]
Household-level attributes				
Household head sex: Female (ref)				
Six and above	0.017 [−0.063, 0.097]	0.017 [−0.057, 0.091]		
Number of under-five in HH: <2 (ref)				
Male	−0.059 [−0.147, 0.029]	−0.027 [−0.124, 0.071]		
Household size: <6 (ref)				
Two and above	0.205 [0.132, 0.278]***	0.221 [0.143, 0.299]***		
Wealth status: Poor (ref)				
Non-poor	−0.253 [−0.325, −0.182]***	−0.364 [−0.444, −0.283]***		
Community-level attributes				
Urban	0.604 [0.470, 0.737]***	0.681 [0.521, 0.840]***	0.704 [0.543, 0.863]***	
Place of residence: Rural (ref)				
Urban	−0.180 [−0.296, −0.064]***	−0.315 [−0.441, −0.189]***	−0.564 [−0.684, −0.445]***	

Region: Established (ref)				
Emerging	0.518 [0.443, 0.593]***	0.687 [0.596, 0.778]***	0.783 [0.692, 0.874]***	
Individual-level attributes				
Health facility	−0.018 [−0.123, 0.086]			
Place of birth: Home (ref)				
24–59 months	−1.004 [−1.100, −0.910]***			
Child age in months: 6–23 months (ref)				
Birth order: First (ref)				
5th and above	0.114 [0.002, 0.226]**			
2nd to 4th order	0.038 [−0.054, 0.133]			
Size at birth: Large (ref)				
Small	0.059 [−0.026, 0.143]			
Average	−0.054 [−0.130, 0.022]			
Undernourished	0.411 [0.345, 0.477]***			
Nutritional status: Nourished (ref)				
Maternal education: Primary+ (ref)				
Duration of breastfeeding: Never (ref)				
No education	0.028 [−0.053, 0.110]			
Less than 12 months	0.090 [−0.120, 0.299]			
12 and above months	−0.020 [−0.219, 0.180]			
Partner's education: Primary+ (ref)				
No education	0.066 [−0.006, 0.137]*			
Mother's anemia: Non-anemic (ref)				
Yes	−0.294 [−0.359, −0.228]***			
Anemic	0.548 [0.474, 0.621]***			
Survey period: 2005–2011 (ref)				
2012–2016	0.337 [0.267, 0.406]***			
Maternal employment: No (ref)				
Constant	0.208 [−0.054, 0.471]	−0.002 [−0.124, 0.121]	−0.057 [−0.121, 0.007]*	0.196 [0.140, 0.252]***
Random effects				
Household level variance	0.029 [0.009, 0.093]	0.467 [0.318, 0.684]	0.484 [0.334, 0.703]	0.563 [0.403, 0.786]
Community level variance	0.001 [0.000, 0.006]	0.199 [0.157, 0.252]	0.221 [0.176, 0.277]	0.301 [0.244, 0.369]
MOR community	1.001	1.530	1.565	1.687
MOR household	1.176	1.919	1.942	2.046
ICC community	0.000	0.050	0.055	0.072
ICC household	0.001	0.118	0.121	0.136
Model fit				
BIC (smaller is better)	22,406.03	23,631.96	23,713.69	24,041.54
AIC (smaller is better)	22,219.29	23,554.11	23,666.98	24,018.18
LR test (Chi^2)	13.10***	260.84***	298.34***	454.57***

*p < 0.1, **p < 0.05, ***p < 0.01
Source: Authors analysis using EDHS 2005–2016

Continued multilevel analysis results

After incorporating household-level factors in Model II, regional and residential disparities in childhood anemia remained evident. Children born in emerging regions continued to show a significantly higher likelihood of anemia than those in established regions, and rural residence was associated with an increased risk relative to urban residence ($p < 0.001$). Household composition also played an important role: children living in households with at least one additional child under five years of age were significantly more likely to be anemic compared with those from households without another under-five child ($p < 0.001$). In contrast, children residing in non-poor households experienced a significantly lower probability of anemia than those from poor households ($p < 0.001$).

In the fully adjusted model (Model III), several factors retained their independent associations with childhood anemia. Residence in emerging regions, living in rural areas, and belonging to poor households were all associated with a significantly increased likelihood of anemia compared with residence in established regions, urban settings, and non-poor households, respectively ($p < 0.001$). Age was also a strong predictor, as children aged 6–23 months were more likely to be anemic than those aged 24–59 months. Higher birth order was associated with increased risk, with children of fifth or higher birth order showing a significantly greater likelihood of anemia compared with first-born children ($p < 0.05$). Nutritional status remained an important determinant, as undernourished children (stunted, wasted, or underweight) had significantly higher odds of anemia than well-nourished children ($p < 0.001$).

Maternal characteristics further contributed to childhood anemia risk. Children born to anemic mothers had a significantly elevated likelihood of anemia ($p < 0.001$), as did those whose mothers were unemployed compared with children of employed mothers ($p < 0.001$). Temporal variation was also evident, with childhood anemia being significantly more prevalent during the 2005–2011 survey period than in 2012–2016 ($p < 0.001$). Conversely, household size, sex of the household head, place of delivery, perceived size at birth, maternal education, and partner's education did not show statistically significant associations with childhood anemia in the multilevel framework ($p \geq 0.05$).

Assessment of random effects demonstrated a marked reduction in unexplained variation after the inclusion of covariates. Community-level variance declined sharply from 0.301 in the null model to 0.001 in Model III, indicating that much of the initial regional and rural–urban variation was explained by the included variables. Similarly, household-level variance decreased from 0.563 in the null model to 0.029 in the final model, suggesting residual but reduced heterogeneity at the household level.

Consistent patterns were observed in the Median Odds Ratio (MOR). Community-level MOR decreased from 1.687 in the null model to 1.001 in Model III, while household-level MOR declined from 2.046 to 1.176, reflecting diminishing unexplained variation across communities and households. Model fit statistics further supported the superiority of the final model. The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values fell from 24,018.18 and 24,041.54 in the null model to 22,219.29 and 22,406.03 in Model III, respectively, indicating improved explanatory performance. Likelihood ratio tests confirmed the statistical significance and appropriateness of the fitted multilevel models.

Theil decomposition trend analysis results

The results of the Theil decomposition trend analysis are presented in **Table 4**. Changes in childhood anemia prevalence between 2005 and 2016 were not uniform across regions. Increases in prevalence were observed in Afar, Oromia, SNNPR, Harari, Addis Ababa, and Dire Dawa, whereas notable declines occurred in Tigray, Amhara, Somali, Benishangul, and Gambella over the same period.

Relative regional inequality in childhood anemia peaked in 2011, with a Theil index value of 0.806. Overall inequality declined over time, decreasing from 0.620 in 2005 to 0.548 in 2016. Decomposition of the Theil index revealed that the vast majority of total inequality was attributable to disparities within regions rather than between regions. Within-region inequality accounted for 98.87% of total inequality in 2005, 97.39% in 2011, and 96.90% in 2016. The contribution of within-region inequality was highest in 2011, corresponding to the year with the greatest overall inequality.

Analysis of pooled data across survey years showed marked regional differences in childhood anemia prevalence. The highest prevalence was recorded in the Somali region (78.68%), followed by Afar (72.76%). In contrast, the lowest prevalence levels were observed in Amhara (41.01%), Addis Ababa (42.64%), and SNNPR (44%) **(Table 4).**

Table 4. Theil decomposition analysis results (N = 17,766), Ethiopia, EDHS 2005–2016

Region	2005 Theil's Index	2005 Anemia (%)	2011 Theil's Index	2011 Anemia (%)	2016 Theil's Index	2016 Anemia (%)	Pooled Theil's Index	Pooled (2005–2016) Anemia (%)
Amhara	0.650	52.22	1.031	35.67	0.852	42.68	0.891	41.01
Tigray	0.564	56.69	0.973	37.78	0.614	54.11	0.739	47.77
Afar	0.495	60.95	0.288	75.00	0.288	74.97	0.318	72.76
Benishangul	0.679	50.73	0.766	46.51	0.838	43.27	0.782	45.75
Oromia	0.570	56.55	0.648	52.29	0.416	66.00	0.546	57.90
Gambela	0.474	62.23	0.682	50.54	0.564	56.90	0.611	54.29
Somali	0.182	83.33	0.364	69.52	0.183	83.27	0.240	78.68
SNNPR	0.780	45.85	0.994	37.01	0.671	51.12	0.821	44.00
Addis Ababa	0.836	43.33	1.105	33.14	0.705	49.41	0.852	42.64
Harari	0.554	57.49	0.598	55.00	0.406	66.61	0.524	59.20
Dire Dawa	0.469	62.57	0.449	63.82	0.323	72.37	0.393	67.52
Total inequality	0.620		0.806		0.548		0.672	
Between-region inequality	0.008 (1.13%)		0.021 (2.61%)		0.018 (3.10%)		0.016 (2.38%)	
Within-region inequality	0.613 (98.87%)		0.785 (97.39%)		0.531 (96.90%)		0.656 (97.62%)	

Source: Authors analysis using EDHS 2005–2016

Findings from the multivariate decomposition analysis

Table 5 summarizes the results of the multivariate decomposition analysis assessing disparities in childhood anemia between emerging and non-emerging regions during the 2005–2016 period. The analysis separated the overall regional gap into components arising from differences in population composition and components resulting from variations in the influence of those characteristics.

Nearly half (47.12%) of the regional disparity in childhood anemia was attributable to differences in observed characteristics between regions, indicating that unequal distributions of key determinants played an important role. The remaining 52.88% of the disparity was explained by differences in regression coefficients, suggesting that similar characteristics exerted unequal effects across regions.

Further breakdown of the explained component showed that reducing inequalities related to household socioeconomic position, maternal anemia status, and maternal employment could lead to meaningful reductions in regional differences in childhood anemia. Equalizing these factors was estimated to decrease the disparity by 12.91%, 13.83%, and 14.15%, respectively. Conversely, existing gaps in household wealth and maternal employment were found to significantly intensify regional inequality, contributing to increases of approximately 25.34% and 23.64%, respectively ($p < 0.01$).

Table 5. Multivariable decomposition of childhood anemia disparities between emerging and non-emerging regions, EDHS 2005–2016

Category	SE	Coefficient	p-value	z-statistic	95% CI	Percentage Contribution

Due to difference in coefficients (C)						
Socioeconomic status	0.013	-0.050	0.000	-3.96	[-0.075, -0.025]	-25.34
Place of residence	0.003	0.004	0.171	1.37	[-0.002, 0.011]	2.23
Child age in months	0.039	0.057	0.141	1.47	[-0.019, 0.133]	28.73
Number under-five in HH	0.037	0.032	0.390	0.86	[-0.040, 0.103]	15.82
Undernutrition	0.011	-0.011	0.331	-0.97	[-0.033, 0.011]	-5.44
Birth order	0.032	0.015	0.633	0.48	[-0.048, 0.079]	7.77
Maternal anemia	0.005	-0.003	0.505	-0.67	[-0.013, 0.007]	-1.72
Partner's education	0.011	0.032	0.002	3.07	[0.012, 0.053]	16.24
_cons (constant)	0.061	0.076	0.214	1.24	[-0.044, 0.196]	38.23
Maternal employment	0.010	-0.047	0.000	-4.74	[-0.067, -0.028]	-23.64
Overall						
Overall gap	0.010	0.199	0.000	21.63	[0.181, 0.217]	100.0
Characteristics gap (E)	0.008	0.094	0.000	12.56	[0.079, 0.108]	47.12
Coefficients gap (C)	0.011	0.105	0.000	9.58	[0.084, 0.127]	52.88
Due to difference in characteristics (E)						
Socioeconomic status	0.004	0.026	0.000	6.28	[0.018, 0.033]	12.91
Place of residence	0.002	-0.0002	0.912	-0.11	[-0.004, 0.004]	-0.11
Birth order	0.001	0.001	0.205	1.27	[-0.0004, 0.002]	0.34
Number under-five in HH	0.002	0.006	0.007	2.72	[0.002, 0.010]	2.88
Child age in months	0.0003	-0.003	0.000	-10.71	[-0.0035, -0.0024]	-1.48
Partner's education	0.001	0.010	0.003	2.92	[0.003, 0.015]	4.56
Undernutrition	0.00002	0.0001	0.000	3.91	[0.0001, 0.036]	0.36
Maternal employment	0.004	0.028	0.000	7.44	[0.021, 0.036]	14.15
Maternal anemia	0.004	0.028	0.000	6.68	[0.019, 0.036]	13.83

This study applied multilevel modeling, Theil index decomposition, and multivariate decomposition techniques to investigate changes and drivers of regional disparities in childhood anemia in Ethiopia using three rounds of nationally representative survey data spanning 2005–2016. The pooled weighted analysis indicated that 54.77% of Ethiopian children aged 6–59 months were anemic. This prevalence exceeds reported levels in Sudan (50.8%) [33] and Uganda (50%) [34], yet remains lower than estimates from Nigeria (68.1%) [35], highlighting the persistent public health concern of childhood anemia in Ethiopia.

Findings from the multilevel analysis demonstrated that factors operating at community, household, and individual levels jointly shaped the observed burden of childhood anemia. This aligns with earlier evidence from Ethiopia [15] and other Sub-Saharan African countries [36]. At the community level, children residing in emerging regions and rural settings faced a markedly higher risk of anemia compared with those living in established regions and urban areas, consistent with prior national studies [37]. Such disparities may reflect unequal socioeconomic conditions, differential access to health and nutrition services, variations in educational attainment, and differences in cultural norms and child-feeding practices [15]. Urban residence may confer protective advantages through improved access to education, health information, income opportunities, and overall living conditions, whereas rural residence is often closely linked to poverty-related constraints [15].

At the household level, economic status measured through the asset-based wealth index showed a strong association with childhood anemia. Children from economically disadvantaged households experienced a higher likelihood of anemia than those from wealthier households. This relationship is plausibly explained by limited access to diverse and nutrient-rich foods among poorer households, given that anemia is largely driven by nutritional deficiencies [36]. Consistent with this explanation, children who were stunted, wasted, or underweight exhibited a greater risk of anemia than adequately nourished children. These findings reinforce the close interconnection between malnutrition and anemia [36]. Maternal employment status also emerged as an important determinant: children of employed mothers were less likely to be anemic than those whose mothers were unemployed, potentially reflecting improved household income and greater capacity to afford nutritious foods. Furthermore, maternal anemia was strongly associated with childhood anemia, suggesting intergenerational transmission of nutritional deficiencies, particularly iron deficiency, from mother to child [38].

Results from the Theil index analysis indicated a modest decline (13.14%) in relative regional inequality in childhood anemia, decreasing from 0.620 in 2005 to 0.548 in 2016. This reduction may be attributed to sustained national and global health initiatives, including the Millennium Development Goals (MDGs), the Health Extension Program (HEP), child survival strategies, national nutrition programs, the Seqota Declaration, and successive Growth and Transformation Plans implemented across regions. Despite this progress, the analysis revealed that most of the observed inequality was driven by disparities within regions rather than between regions. Pooled data further showed that childhood anemia prevalence was highest in Somali (78.68%) and Afar (72.76%) regions, while substantially lower levels were observed in Amhara (41.01%), indicating a pronounced concentration of anemia in emerging regions. This pattern may be explained by the greater vulnerability of Somali and Afar regions to drought and malaria, both of which can directly or indirectly exacerbate childhood anemia [19].

The multivariate decomposition analysis provided additional insights into the sources of regional inequality. More than half (52.88%) of the disparity in childhood anemia between emerging and non-emerging regions was attributable to differences in the effects of determinants (unexplained component), while 47.12% was explained by differences in observed characteristics. Household economic status, maternal anemia, and maternal employment were key contributors to these inequalities. Addressing disparities in these factors could reduce the anemia gap between emerging and non-emerging regions by approximately 12.91%, 13.83%, and 14.15%, respectively. These findings emphasize the importance of targeted interventions that address socioeconomic inequities, maternal health, and employment opportunities to mitigate regional disparities in childhood anemia.

The study has notable strengths and limitations. A major strength lies in the use of nationally representative data covering all former regions of Ethiopia, enhancing the generalizability of the findings. The application of advanced inequality and decomposition methods also allowed for a nuanced understanding of regional disparities. However, several limitations should be acknowledged. The use of repeated cross-sectional survey data limits causal inference. Additionally, reliance on self-reported information may introduce recall bias, particularly among mothers with limited literacy, potentially leading to reporting errors. The analysis focused on well-established determinants of childhood anemia; however, other relevant factors such as household food insecurity, complementary feeding practices, and dietary diversity were not captured. Finally, broader macro-level influences, including policy implementation, financing, and governance, were beyond the scope of this study.

Conclusion

Over an 11-year period, Ethiopia achieved only a modest (13.14%) reduction in regional inequalities in childhood anemia, indicating slow progress in narrowing disparities. Approximately one-third of the observed change in inequality was driven by differences in measurable population characteristics. Household wealth status, maternal anemia, and maternal employment played pivotal roles in both reducing and exacerbating regional differences in childhood anemia throughout the study period. These findings underscore the need for policy and programmatic efforts that specifically target socioeconomic disadvantage, improve maternal nutritional status, and expand employment opportunities for women—particularly in emerging regions—to effectively reduce regional inequalities in childhood anemia.

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