Subnational trends and inequities of under-immunization among children aged 12-23 months in Uganda

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Introduction

Immunization stands as one of the most powerful and cost-effective interventions for preventing diseases and saving lives [1, 2]. Despite large efforts worldwide, millions of children do not receive all recommended vaccines, slowing the reduction of mortality rates [3]. An estimated 25 million children globally are either unvaccinated or under-vaccinated, with 18 million having received no vaccines at all [4].

The World Health Organization (WHO) reported that, in 2018, approximately 19%, 26%, 27%, and 30% of children in the least developed countries did not receive BCG, the third dose of DTP, the third dose of polio, and PCV, respectively [6]. As of 2020, an estimated 80% of the 17.1 million children who had not received the first dose of the Diphtheria-Tetanus-Pertussis vaccine (DTP1) belonged to low-income countries [7]. The number of zero-dose children reported has increased by 3.5 million children since 2019 [7]. In 2012, the World Health Assembly endorsed the global vaccine action plan, aiming to have all children worldwide vaccinated by 2020 [5], ensuring universal access to immunization for every child, regardless of location, identity, or residence [5].

Governments worldwide have allocated billions of dollars to immunization programs, recognizing their substantial economic benefits in saving lives and curbing hospitalization costs (Ref). The return on investment for every 1 US dollar spent is estimated to be between 20 and 50 US dollars (Ref). Nations achieving high levels of fully immunized children not only enjoy a healthier population but also gain a competitive edge in economic productivity compared to those with inadequate immunization schedules (Ref). Projections suggest that achieving full immunization could prevent 24 million people from falling into poverty by 2030 (Ref).

In Uganda, national coverage for full vaccination has seen slow progress over the past decade, reported at 46%, 52%, and 55% in 2006, 2011, and 2016, respectively [8]. Despite Uganda's early adoption of the Reaching Every District (RED) initiative in 2004, aimed at increasing coverage and equity in immunization across communities [9–11], regional immunization imbalances persist as a challenge [8, 12]. Despite various interventions such as the Uganda National Expanded Program on Immunization (UNEPI) [13] and the Maternal and Child Health Integrated Program (MCHIP) [9], designed to strengthen routine immunization, a significant number of children in Uganda remain unvaccinated [8].

The 2016 Uganda Demographic and Health Survey reveals that almost half (45%) of children aged 12-23 months had not received all basic vaccinations at the time of the survey [8]. Moreover, only half (49%) of these children received vaccinations by the recommended age [8]. While various health indicators have been estimated in past surveys in Uganda, detailed subnational trends remain unknown. For example, the analysis of the 2000-01 UDHS was region-based, encompassing four regions (Central, West, North, and East) [14]. In 2006, estimates were provided based on nine sub-regions (Central 1, Central 2, Kampala, East Central, Eastern, North, West Nile, Western, and Southwest) [15]. The 2011 UDHS considered ten sub-regions, adding Karamoja to the list [16], and the most recent survey included 15 sub-regions [8]. Consequently, with the introduction of new sub-regions in each survey, subnational trends and associated inequities in immunization indicators remain uncertain.

Hence, it is crucial for this study to identify and understand the disadvantaged or marginalized populations that remain underserved, particularly concerning zero-dose and under-immunization. To achieve this, the study will reconstruct all sub-regions for the years 2022, 2016, and 2011, aligning them with those of 2006. This approach aims to derive subnational trends and inequities in zero-dose children and under-immunization in Uganda. Additionally, the study will investigate the factors associated with under-immunization and zero-dose among children.

Methods

Data source and population: This study utilized data from three consecutive Uganda Demographic and Health Surveys (UDHS) conducted in 2006, 2011, and 2016. Approval to download and use this data was obtained from the Measure DHS website (www.measuredhs.com) upon request. This study focused exclusively on children aged 12-23 months at the time of the survey. Additionally, children who were not permanent residents in the surveyed households were excluded, as the study aimed to investigate household characteristics as part of its scope.

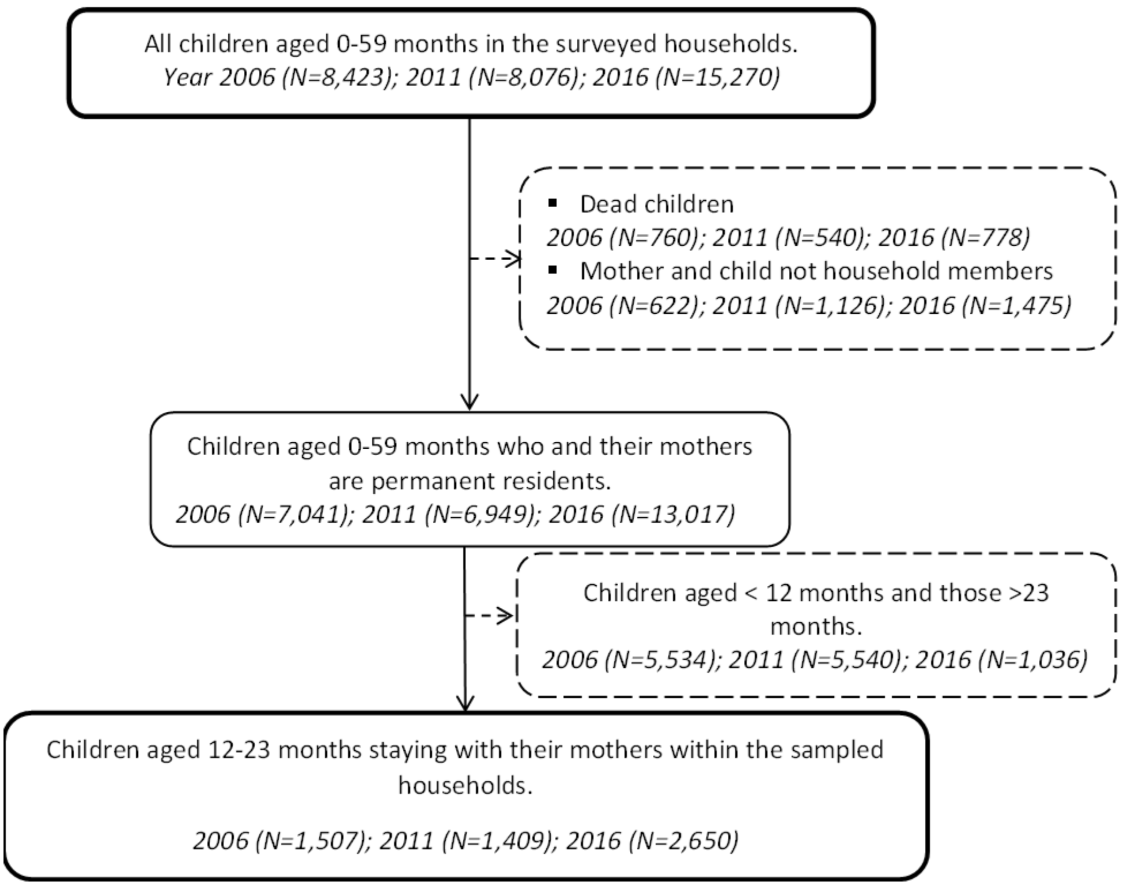


Figure 1: Derivation of the final weighted sample size of the study.

We reconstructed all the subregions in the 2016 and 2011 surveys to align with the nine subregions included in the 2006 survey. This involved aggregating subregions; for example, North and Karamoja in the 2006 survey were combined to create "North" with delineations similar to those in the 2006 survey. Supplementary Table # illustrates the new regions that were generated in each of the surveys.

Variables and their measurements

Operational Definitions

Complete Immunization: children aged 12-23 months who have received at least one dose of BCG, three doses of pentavalent, three doses of polio, and one dose of measles.

Under-immunization: children aged 12-23 months who received at least one dose of the vaccines above but not all the doses.

Zero-dose: children aged 12-23 months who did not receive a single dose of vaccines listed above.

Outcome variables: The study focused on two primary outcomes: under-immunization and zero-dose vaccination, both derived from the immunization information provided by mothers during interviews. Data were collected through vaccination cards and verbal reports from mothers. Mothers were asked about their children's receipt of BCG, oral polio vaccine, DPT/pentavalent, measles vaccination, and polio vaccination. For oral polio and DPT, additional information on the number of vaccine administrations was obtained. In cases where mothers couldn't recall the child's vaccination status, the child was considered non-immunized for that specific vaccine. Each vaccine dose had five response categories: no vaccination, vaccination date on the card, reported by mothers, vaccination marked on the card, and DK (don't know).

Equity stratifier: Based on existing literature (Ref), we considered the following equity stratifiers: place of residence (rural vs. urban), subnational regions, maternal education, and household wealth quintile. Place of residence and sub-national regions (which were specifically divided into nine regions: Kampala, Central, East-central, Eastern, Western, West-Nile, Northern, and South-west) defined the geographical location dimension. On the other hand, maternal education categorized as no-education, primary education, and secondary education/higher, and household wealth index were the measures of socioeconomic status. The UDHS employed principal component analyses (Ref) on a list of household assets (e.g., radio, television, car), dwelling characteristics (e.g., flooring material), type of drinking water source, toilet facilities, electricity, among others, to generate the wealth index. This resulted in a wealth score that was used to classify the households into five equally sized groups, the wealth quintiles. The quintiles range from the first, including the 20% poorest households, to the fifth, including the 20% richest households.

Statistical analysis

We carried out the analyses in four different steps. Firstly, we performed a descriptive analysis of the background characteristics of women who had children aged 12-23 months within the sampled households using frequencies and percentages.

Measures of inequality

We employed three absolute measures and three relative measures of equity, chosen for their appropriateness and relevance, as well as their widespread adoption in health studies (Ref).

Absolute measures of inequality

We utilized the high-to-low absolute difference, which shows the health disparity between the best- and worst-performing regions. This was calculated following:

$$Absolute\ difference = y_{high} - y_{low}$$

Additionally, the Weighted Mean Difference from the Mean (MADM) highlighted the health differences in each subregion or place of residence, considering weighted factors in relation to a reference point:

$$Weighted\ MADM = \frac{\sum_j pop_j \times |y_j - y_{ref}|}{pop}$$

Where: y_j is the estimate for each specified subregion or place of residence j; pop_j denotes the weighted sample size for each specified subregion or place of residence j; pop is the overall weighted sample size.

Furthermore, the Slope Index of Inequality (SII) was employed to assess the absolute difference in predicted health outcomes between the most advantaged and disadvantaged children. The SII was calculated through a logistic regression model after downloading the slope index of inequality ado-file for binary outcomes using the command: net install siilogit, from ("https://www.equidade.org/files"). Its computation was restricted to ordered dimensions (education and economic status) and requires ranking of a weighted sample in order from the most disadvantaged (rank 0) to the most advantaged (rank 1) subgroups. The poorest and uneducated individuals were considered the most disadvantaged, but those that have completed secondary education and the richest subgroups were deemed most advantaged. Then, the outcome was predicted for those at the two extremes and the difference in the predicted value between rank 1 and rank 0 produced the SII.

Relative measures of inequality

Low to high relative difference shows the relative difference in health between the best-and worst-performing subregions or place of residence expressed as a percentage of the level of health in the best-performing subregion region or place of residence.

$$Low\ to\ high\ relative\ difference = \frac{y_{(high)} - y_{(low)}}{y_{(low)}} \times 100$$

Additionally, the Mean Absolute Difference to the Mean (MADM) serves as a metric for the average deviation of each subnational or rural-urban unit's indicator value from the national average. This is represented as a percentage of the overall mean level of the health outcome.

$$Weighted\ MRDM = \frac{Weighted\ MADM}{y_{ref}} \times 100$$

The concentration index (CIX) was also employed to assess the relative socioeconomic disparities in under-immunization and zero dose. This index is defined as twice the area between the concentration curve and the line of equality, analogous to the Gini index (Ref). It ranges from -1 to +1, assuming zero as equality. Values farther from zero signify greater relative inequality (Ref), where positive values indicate pro-rich differences and negative values imply pro-poor differences. The assessment involved utilizing commands downloaded from the International Center for Equity in Health (Ref), and the following command was used for installation: net install cixr, from("https://www.equidade.org/files"). Additional information about these measures has been reported elsewhere (Ref), including detailed discussion and procedures for their calculations (Ref).

Equiplots

To examine the patterns of inequality over time, we utilized equiplots—a graphical representation illustrating the disparities in under-immunization across various equity strata (Ref). Developed by the International Center for Equity in Health, the equiplot is a data visualization tool that allows us to simultaneously observe all indicators and their respective coverage levels. This offers a visual representation of absolute inequality (http://www.equidade.org/equiplot.php). All the data in this study were first weighted to ensure its representativeness as required for all DHS data (Ref) and analyses performed in STATA 18.0 software.

Results

Table 1 presents the distribution of the study population across demographic characteristics during the three survey years (2006, 2011, and 2016). The results indicate that the majority of mothers, accounting for 52.9% in 2006 and 55.5% in 2016, fall within the age range of 20-29 years and predominantly reside in rural areas. The subregional distribution is generally uniform across all years, except for Kampala and West Nile, which show slightly lower proportions.

The distribution across wealth quintiles remains relatively consistent over the years, with the highest percentage generally falling within the poor category. Notably, the richest quintile experiences a slight increase from 14.0% in 2006 to 20.2% in 2016. Further, the percentage of mothers with secondary/higher education doubles from 13.7% in 2006 to 29.4% in 2016.

In addition, the percentage of mothers with no education decreases from 20.6% in 2006 to 9.1% in 2016. The marital status of the majority of mothers indicates that almost 9 in 10 are married or living together. Regarding access to media, the majority of the population has exposure to at least one or two sources of media. Notably, there is a slight increase in exposure to all three sources of media, rising from 4.7% in 2006 to 10.9% in 2016.

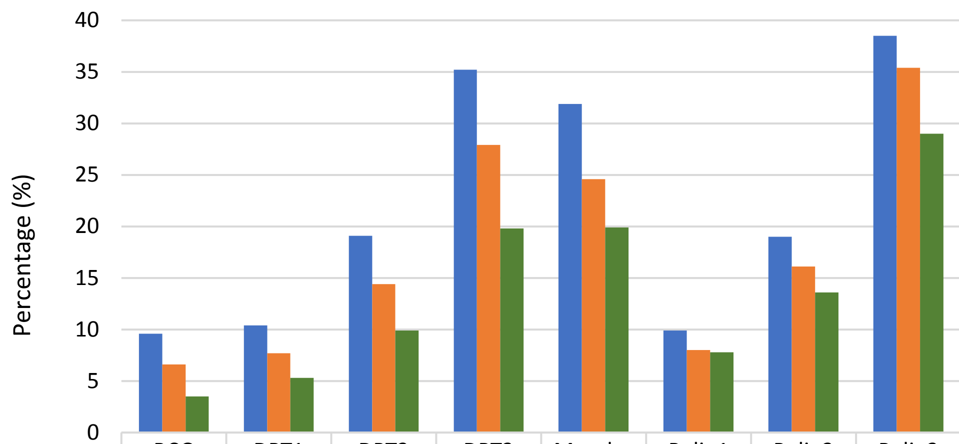
Results also show a decreasing trend in the prevalence of under-immunization from 52.5% in 2006, 47.9% in 2011, to 43.0% in 2016. Similarly, the percentage of zero-dose children also reduces over the years, with a notable decline from 6.7% in 2006 to 1.2% in 2016.

Table 1: Distribution of the study population by selected background characteristics.

Variable	2006	2011	2016

	N=1,507	N=1,409	N=2,650
	N(%)	N(%)	N(%)
Place of residence			
Urban	144(9.6)	189(13.4)	602(22.7)
Rural	1,363(90.4)	1,220(86.6)	2,049(77.3)
Household wealth index			
Poorest	320(21.2)	317(22.5)	586(22.1)
Poorer	360(23.9)	309(21.9)	577(21.8)
Middle	331(22.0)	258(18.3)	497(18.7)
Richer	285(18.9)	261(18.5)	457(17.2)
Richest	211(14.0)	264(18.7)	534(20.2)
Mother's education level			
No education	310(20.6)	184(13.1)	242(9.1)
Primary	990(65.7)	892(63.3)	1628(61.4)
Secondary/Higher	207(13.7)	332(23.6)	780(29.4)
Region			
South central	150(9.9)	146(10.3)	329(12.4)
North central	123(8.2)	156(11.1)	282(10.6)
Kampala	66(4.3)	78(5.6)	122(4.6)
East central	174(11.6)	162(11.5)	276(10.4)
Eastern	256(17.0)	244(17.3)	462(17.4)
North	250(16.6)	197(14.0)	339(12.8)
West-Nile	81(5.3)	74(5.3)	195(7.4)
Western	228(15.1)	184(13.1)	366(13.8)
Southwest	181(12.0)	168(11.9)	280(10.6)
Under-immunization			
Yes	792(52.5)	675(47.9)	1,139(43.0)
No	715(47.5)	734(52.1)	1,511(57.0)
Zero dose			
Yes	101(6.7)	56(3.9)	31(1.2)
No	1,406(93.3)	1,353(96.1)	2,619(98.8)

N is the frequency and % is the percentage



	BCG	DPT1	DPT2	DPT3	Measles	Polio1	Polio2	Polio3
UDHS 2006	9.6	10.4	19.1	35.2	31.9	9.9	19	38.5
UDHS 2011	6.6	7.7	14.4	27.9	24.6	8	16.1	35.4
UDHS 2016	3.5	5.3	9.9	19.8	19.9	7.8	13.6	29

Figure 2: Trends in the proportion of children missing various vaccine doses

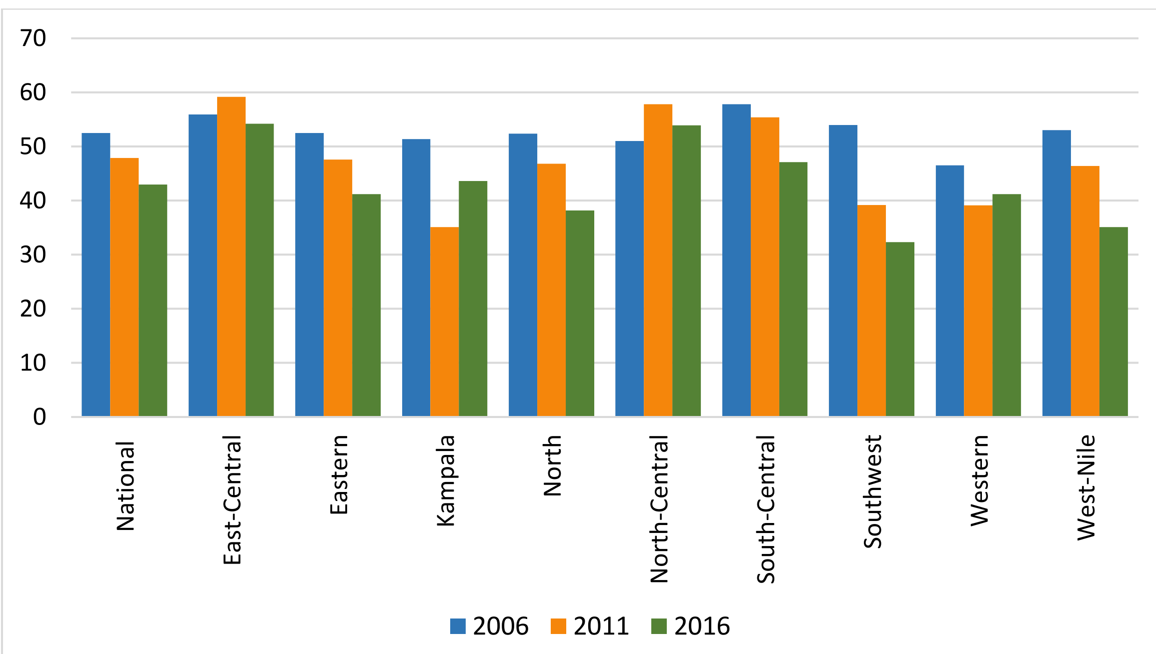


Figure 3: Trends in the prevalence of under-immunization

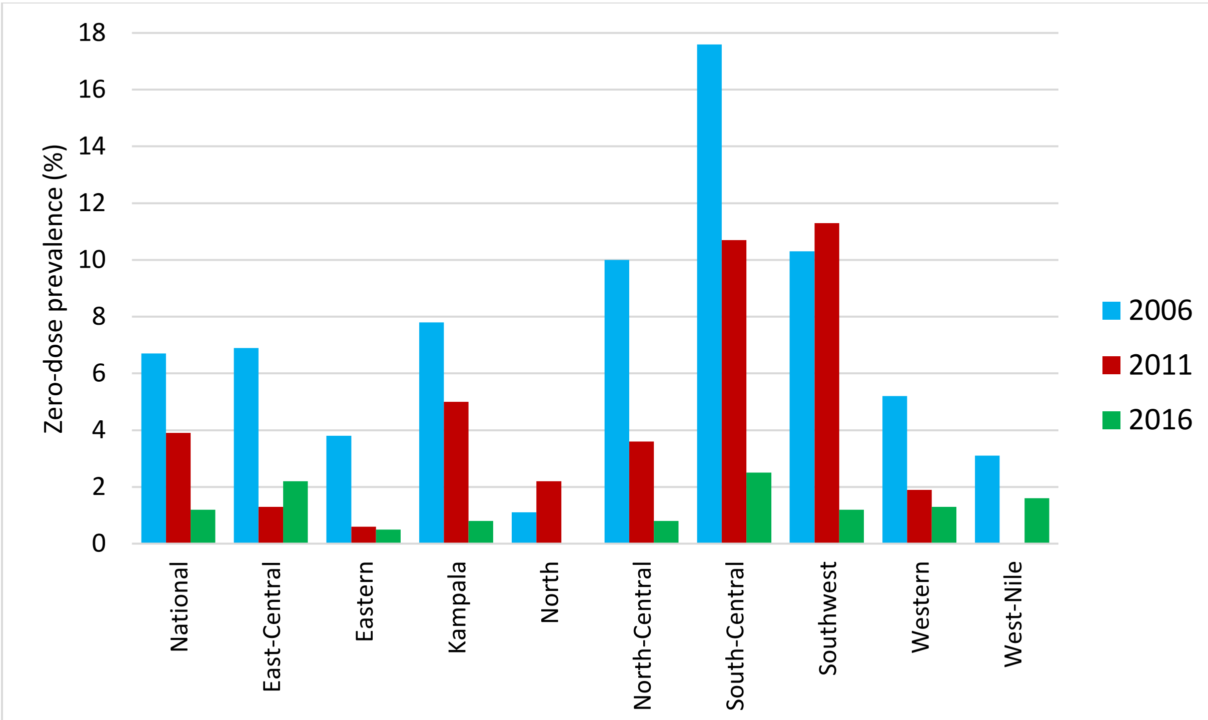


Figure 4: Trends in the prevalence of zero-dose by subregion

Measures of inequality

Table 3 presents the analysis of under-immunization inequality at both subnational and rural-urban levels. At the subnational level, a consistent trend is observed across the three time periods. Findings reveal a substantial and rapid increase in inequality from 2006 to 2011, with absolute and relative differences peaking at 24.3% and 68.7%, respectively, indicating a significant regional disparity in under-immunization rates. The weighted mean relative difference from the overall mean was 13.3%. Subsequently, a slight decrease in inequality occurred between 2011 and 2016.

In terms of rural-urban residence, a distinct pattern emerges. In 2006, the absolute difference was 4.8%, accompanied by a weighted mean absolute difference of 5.1. The relative difference and weighted mean relative difference were 10.0% and 9.7%, respectively. In 2011, there was an increase in absolute difference (10.5%) and a decrease in relative difference (2.4%), indicating a shift in the nature of rural-urban inequality. By 2016, both absolute and relative differences were minimal (0.4% and 0.1%, respectively), signifying a significantly reduced gap in under-immunization rates between rural and urban areas.

Table 3: Subnational and rural-urban inequality in under-immunization according to the selected absolute and relative measures.

Stratifier	**Absolute measures**		**Relative measures**	
	High to low absolute difference	Weighted mean absolute difference from the overall mean	High to low relative difference (%)	Weighted mean relative difference from overall mean (%)
Subnational level				
2006	11.3	2.2	24.3	4.2
2011	24.1	6.4	68.7	13.3
2016	21.9	5.8	67.8	13.4
Rural-urban residence				
2006	4.8	5.1	10.0	9.7
2011	10.5	2.4	27.1	5.1
2016	0.4	0.1	0.9	0.3

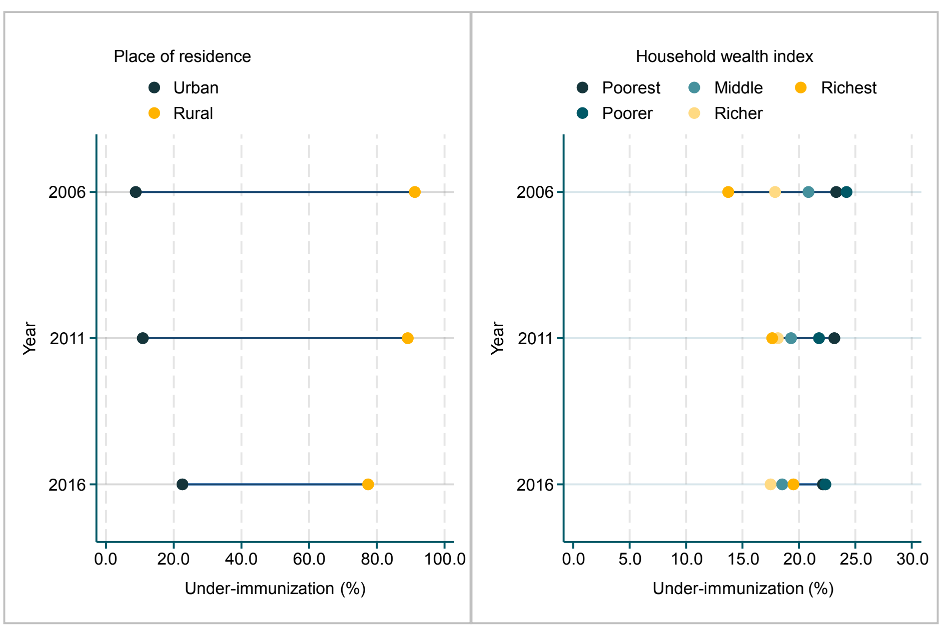
Table above displays both relative and absolute measures of inequality concerning under-immunization and zero-dose, categorized by maternal education and household wealth. Positive values in the Relative Concentration Index (RCI) and Slope Index of Inequality (SII) imply a greater concentration of under-immunization among children whose mothers are in the wealthiest quintile or have completed secondary/higher education. Conversely, negative RCI and SII values indicate a higher concentration of under-immunization among children from the poorest quintile or those whose mothers lack formal education.

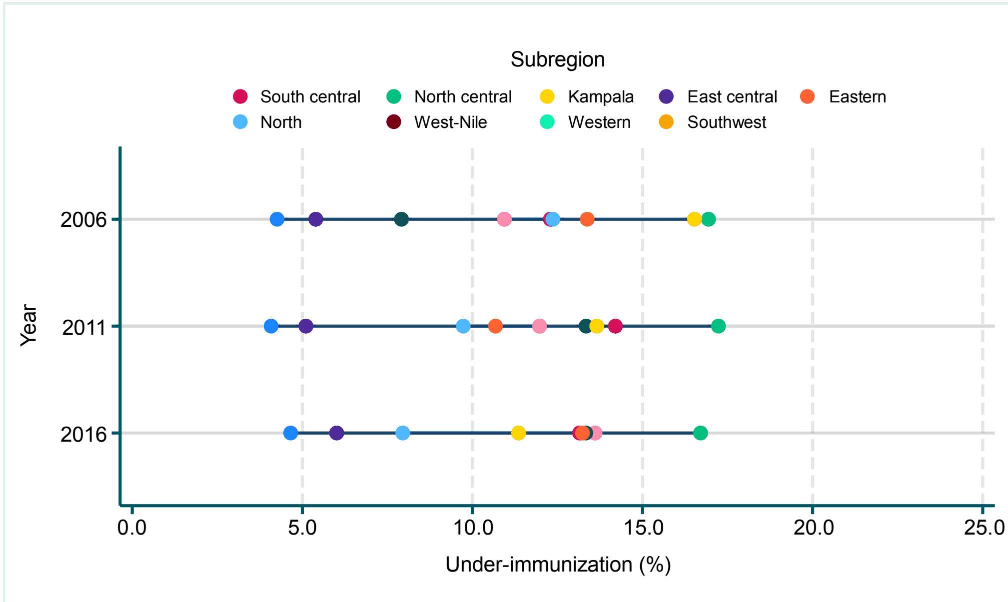
Throughout all years, under-immunization is consistently more prevalent among children whose mothers have lower socioeconomic status, particularly those from the poorest households and those with mothers lacking any formal education. Additionally, the RCI and SII values suggest that the level of inequality is more pronounced for maternal education than household wealth.

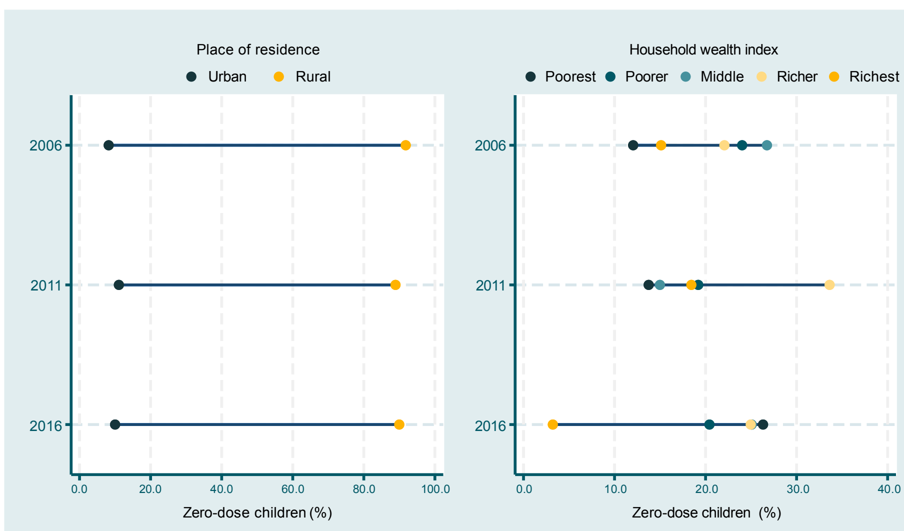
Furthermore, the results demonstrate a decreasing trend in the absolute inequality of under-immunization across wealth quintiles from 2006 (RCI=0.066, SII=0.088) to 2016 (RCI=0.028, SII=0.016). Similarly, for maternal education, inequality in under-immunization has decreased over the same period (RCI: 0.085, SII: 0.029 in 2006 to RCI: 0.042, SII: 0.088 in 2016), with a slight increase in 2011 (RCI: 0.091, SII: 0.219). In the case of zero-dose, the inequality across household wealth has diminished from 2006 (RCI=0.094) to 2016 (RCI=0.047). A similar trend is also observed across maternal education.

Outcome	Stratifier	Slope Index of Inequality (SII) Coeff(Std. err.)	Relative concentration index (RCI) Coeff (Std. err.)
Under immunization	**Household wealth index**		
	2006	-0.088(0.054)	-0.066(0.007)
	2011	-0.044(0.058)	-0.074(0.008)
	2016	-0.016(0.038)	-0.028(0.006)
	Maternal education level		
	2006	-0.209(0.060)	-0.085(0.010)
	2011	-0.219(0.062)	-0.091(0.010)
	2016	-0.088(0.045)	-0.042(0.007)
Zero-dose	**Household wealth index**		
	2006	0.043(0.024)	-0.088(0.007)
	2011	0.034(0.025)	-0.109(0.008)
	2016	-0.009(0.007)	-0.047(0.006)
	Maternal education level		
	2006	-0.048(0.024)	-0.094(0.010)
	2011	0.002(0.039)	-0.093(0.011)
	2016	-0.027(0.011)	-0.056(0.007)

Inequities in under-immunization




Subregion
South central
North central
Kampala
East central
Eastern
North
West-Nile
Western
Southwest
Year
2006
2011
2016
0.0
5.0
10.0
15.0
20.0
25.0
Under-immunization (%)


Place of residence
Urban
Rural
2006
2011
2016
0.0
20.0
40.0
60.0
80.0
100.0
Zero-dose children (%)
Household wealth index
Poorest
Poorer
Middle
Richer
Richest
2006
2011
2016
0.0
10.0
20.0
30.0
40.0
Zero-dose children (%)