Health-economics of vaccines in Ethiopia

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Chapter five

PERSISTENT SOCIOECONOMIC INEQUALITIES IN MEASLES VACCINE UPTAKE IN ETHIOPIA IN THE PERIOD 2005–2016

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ABSTRACT

Objective

This study aims to quantify socioeconomic inequalities—and the factors contributing to these inequalities—in measles vaccine uptake among children aged 12–23 months in Ethiopia between 2005 and 2016.

Methods

Inequalities in measles vaccine uptake were investigated based on data from the Ethiopian Demographic and Health Surveys conducted in 2005, 2011, and 2016. Concentration curves and concentration indices were used to measure the degree of inequality, and decomposition analysis was used to identify factors contributing to these inequalities.

Results

The overall level of national measles vaccine uptake in Ethiopia exhibited an increasing trend between 2005 and 2016. As indicated by the concentration index of measles vaccine uptake, however, which was estimated at 0.202 ($p<0.01$) in 2005, 0.226 ($p<0.01$) in 2011, and 0.223 ($p<0.01$) in 2016, measles vaccine uptake became consistently more concentrated among children from more affluent households. The dominance test of the concentration curve further confirmed that the persistence of inequalities in measles vaccine uptake over time. Various factors— including maternal educational level, antenatal care use, institutional delivery, and exposure to media—were identified as the most important contributors to the inequalities.

Conclusions

Even though the national measles vaccine uptake showed improvement between 2005 and 2016, socioeconomic inequalities in the uptake persisted over time. Efforts to improve the national immunization coverage should be accompanied by appropriate measures to address the inequalities.

INTRODUCTION

Measles is a highly contagious viral illness characterized by fever, cough, conjunctivitis and the presence of Koplik spots. The infection can cause severe illness, permanent complications, and death [1–3]. Measles is best prevented through vaccination. A safe and effective measles vaccine has been in use since the 1960s [4]. In the period 2000 to 2018, measles vaccinations prevented more than 23 million measles-associated mortalities worldwide [5]. The disease was eliminated in some parts of the world after achieving and sustaining high (≥95%) measles vaccination coverage [6]. Measles nevertheless continues to be one of the major global public health problems of our time, particularly in developing countries. According to the World Health Organization (WHO), 110,000 measles-related deaths occurred worldwide in 2017, most occurring among children younger than five years of age [5].

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In Ethiopia, even though the number of under-five mortalities caused by measles decreased from 717 to 87 deaths per 100,000 persons between 1990 and 2013 [7], ongoing outbreaks have been reported in different parts of the country each year [8–13]. These outbreaks are apparently linked to suboptimal national measles vaccination coverage [14]. In addition to significant morbidity and mortality, these outbreaks have been associated with a considerable economic burden in the country [15].

Although measles vaccine uptake in Ethiopia increased to 54% in 2016 from its lowest level of about 10% in 1980s, the uptake is far short of the 95% uptake needed to prevent measles epidemics [16,17]. Compared to other vaccinations that are provided at the beginning of the routine immunization schedule like Bacillus Calmette–Guérin (BCG), the measles vaccine uptake is lower, thus implying that some children who start the immunization schedule eventually drop out later before receiving the measles vaccine [16,17]. Moreover, the improvements that have been achieved in Ethiopia with regard to national measles vaccine uptake have been characterized by substantial differences among population subgroups (e.g., between the richest and poorest segments). Such differences indicate that certain vulnerable groups are under-served [16].

Closing the equity gap in the national immunization program is essential to ensuring that nobody is left behind [18,19]. Data on inequalities and their development over time have clear implications for designing evidence-based strategies that could help to improve vaccination uptake among the most disadvantaged groups, in addition to paving the way for universal vaccination coverage. Previous research in Ethiopia has investigated socioeconomic inequalities in measles vaccination, along with the factors associated with these inequalities [20]. This analysis nevertheless ignores several potential predictors, including exposure to media, antenatal care utilization, and institutional delivery. In addition, new data from the 2016 Ethiopian Demographic and Health Survey (EDHS) have been made available for the public use since the aforementioned study was conducted. The current study therefore, aims to provide updated and detailed evidence on trends and predictors of socioeconomic inequalities in measles vaccine uptake in Ethiopia between the 2005 and 2016.

METHODS

Study Data

Data were obtained from three rounds of the EDHS (2005, 2011 and 2016) and used to analyze the trends in socioeconomic inequalities in measles vaccine uptake. The EDHS consists of nationally representative household surveys that are designed to provide a range of current evidence on a variety of topics, including health and childhood immunization. The surveys employ a stratified multi-stage, random sampling design. Detailed survey methodology is available in the respective EDHS reports [16,21,22].

Variables

The outcome variable in this study is the measles vaccine uptake among children aged 12–23 months. Ethiopian's national schedule for the Expanded program on Immunization (EPI) calls for children to receive all childhood vaccinations – including measles vaccine—between the ages of 12 and 23 months. Measles vaccine uptake is recorded as a binary variable, indicating whether a child has received the recommended measles vaccine or not (vaccinated = 1/not vaccinated = 0). The following independent variables are included in this study: maternal age (15–19, 20–34, 35–49 years), maternal educational level (no education/primary/secondary/higher), maternal employment status (working/not working), maternal religious affiliation (Orthodox/Protestant/Muslim/others), exposure to media (yes/no), type of residence (urban/rural), region (Tigray/Afar/Amhara/Oromia/Somali/Benishangul-Gumuz/Southern Nations Nationalities and Peoples' Region [SNNPR]/Gambela/Harari/Addis Ababa/Dire Dawa), antenatal care utilization (yes/no), institutional delivery(yes/no), distance to health facility (not big problem/big problem), and sex of the child (female/male). In this study, the asset-based wealth index is used as a proxy for socioeconomic status. The wealth index is constructed by principal component analysis using data on assets ownership and housing characteristics [16,21,22].

Inequality analysis

The degree of socioeconomic inequality in measles vaccine uptake among 12- to 23 month-old children was measured using the concentration curve (CC) and the concentration index (CI) [23]. The CC is obtained by plotting the cumulative proportion of measles vaccination (on the y-axis) against the cumulative proportion of individuals ranked by the socioeconomic status from poorest to richest (on the x-axis). The 45-degree diagonal line from the origin of the plot represents the line of equality. The CC for measles vaccine uptake lies above the line of equality when measles vaccine uptake is disproportionally concentrated among the poor. Conversely, if measles vaccine uptake is more concentrated among the rich, the curve will lie below the line of equality. In the absence of socioeconomic inequality in measles vaccine uptake, the CC will overlap with the diagonal line. The greater the magnitude of inequality is, the wider the gap will be between the line of equality and the CC [23,24].

In our study, the CCs for measles vaccine uptake were plotted using data from three waves of the EDHS: 2005, 2011, and 2016. Dominance tests were used to explore the differences between the CCs for the measles vaccine uptake and the line of equality. Similarly, to assess the changes in inequality over time, the CCs of measles vaccine uptake at two different time points (EDHS 2005 and EDHS 2016) were compared according to the "dominance test". In this study, the dominance tests were carried out following a multiple comparison approach (MCA). In this approach, for example, curve A dominates curve B "if there is at least one quantile point at which curve A lies significantly above curve B and there is no quantile point at which curve B lies above curve A". Following common practice, we applied 19 equally spaced quantile points [23].

To quantify the magnitude of inequalities that are graphically indicated by CCs, the corresponding CIs of measles vaccine uptake were computed. The CI is equal to twice the area between the CC and the line of equality. It can be computed as twice the covariance of the health variable and fractional rank in terms of socioeconomic status, divided by the variable mean as described in the following equation.

$$CI = \frac{2}{\mu_h} cov(h_i, r_i) \quad (1)$$

where h is the health outcome of interest (measles vaccine uptake) for individual i, r_i is the socioeconomic ranking of individual i, and μ_h is the mean of h. The value of the CI can vary between -1 and +1, with negative (positive) CI values indicating a pro-poor (pro-rich) distribution of the health variable of interest. The CI value reflects the degree of inequality. Greater absolute CI values indicate greater inequality in measles vaccine uptake. A CI values of 0 indicates the absence of socioeconomic inequality in measles vaccine uptake [23].

Due to several questionable properties associated with the use of standard CI with bounded and binary health variables, the use of the modified version of the CI is recommended. We therefore use the Erregeyers normalized CI (ECI) as an alternative [25]. The ECI is calculated as follows:

$$ECI = \frac{4\mu_h CI}{b - a} = 8cov(h_i, r_i) \tag{2}$$

where ECI is the Erreygers' concentration index, μ_h is mean health status h (measles vaccine uptake), and CI is the standard concentration index, with *b* and *a* representing the upper and lower bounds of the outcome variable (h). In our study, the range *b*−*a* is unity, as the outcome variable is binary. The ECI is interpreted in the same way as the standard CI.

Decomposition of the concentration index

One important feature of the CI is that it can be decomposed to quantify the contribution of independent variables to the overall level of socioeconomic inequality [26]. Accordingly, the ECI for measles vaccine uptake among children aged 12–23 months was decomposed in order to examine the contribution of each independent variable to the level of inequality in each survey year. The multivariate regression model linking the outcome variable h (measles vaccine uptake) to sets of k independent variables (x_k) is described as follows,

$$h_i = \alpha + \sum\nolimits_k \beta_k x_{ki} + \varepsilon_i \tag{3}$$

such that ECI can be calculated as follows:

$$ECI = 4\left[\sum\nolimits_k \beta_k \overline{x}_k CI_k + GCI_\varepsilon\right] \tag{4}$$

where, X_k is the mean of the k^{th} determinant for measles vaccine uptake, with β_k reflecting the regression coefficients for the determinants, ε_i reflecting the error terms, CI_k being the concentration index of the determinant and GCI_ε being a generalized concentration index for the error term (ε). The contribution of a given variable depends on how it is associated with the measles vaccine uptake (β_k) and how it is distributed across the socioeconomic range (CI_k). The percentage contribution of a given independent variable to the overall observed level of inequality was obtained by dividing its contribution by the ECI of the uptake of measles vaccine.

Our variables of interest—measles vaccine uptake—is binary, and it should therefore best be estimated by non-linear models. In this study, however, we use a linear regression model in order to fulfill the linearity assumption and to facilitate interpretation of the results [23,27]. We nevertheless repeated the analysis using partial effects of probit regression to verify robustness.

In some studies, the socioeconomic ranking variable is included in the regression model during decomposition analysis, often appearing as the main variable explaining the inequality. Other scholars have argued against this practice, however, having demonstrated that the inclusion of the ranking variable in the regression produces artificial results [28,29]. Following the recommendations of these scholars, we did not include a socioeconomic status variable (in this case, a wealth index) when regressing measles vaccine uptake (Equations 3 and 4).

Bootstrapping with 1,000 replications was used to obtain standard errors. Statistical analyses were carried out using Stata version 16 (StataCorp, College Station, TX, USA) and all analyses were adjusted using appropriate sampling weights.

RESULTS

The weighted descriptive statistics of variables are presented in Table 1. Around half of the children between the ages of 12 and 23 months were female (48.9% in 2005, 47.7% in 2011, and 53.8% in 2016). Across all three waves of the survey, the majority of the children were from the Oromia region, from Christian families (Orthodox and Protestant combined) and from rural areas. According to the wealth index, 24.0% of the children were from the poorest households in 2005, with 22.9% of those in 2011 and 25.2% of those in 2016 being from the poorest households. The share of children from the richest households was 16.1% in 2005, 15.9% in 2011, and 14.4% in 2016. Across all periods, the vast majority of the mothers had completed no education, were not exposed to media, did not use antenatal care, and had given birth at home.

Developments in national vaccine uptake from 2005 to 2016 are charted in Fig. 1. The overall national measles vaccine uptake increased from 34.9% in 2005 to 55.7% in 2011, declining to 54.3% in 2016. In all three surveys, the uptake was lowest among children in the poorest households, while it increased with each wealth quintile.

Table 1. Summary statistics for independent variables, EDHS 2005 – EDHS 2016

Variable		EDHS 2005 N(%)‡	EDHS 2011 N(%)‡	EDHS 2016 N(%)‡
Mother's age				
	<20	121(6.4)	109(5.6)	84(4.2)
	20-34	1349(71.9)	1444(74.8)	1467(73.2)
	35-49	407(21.7)	378(19.6)	453(22.6)
Mother's education level				
	No education	1456(77.6)	1307(67.7)	1257(62.7)
	Primary	328(17.5)	522(27)	577(28.8)
	Secondary and Higher	93(4.9)	102(5.3)	170(8.5)
Religion				
	Orthodox	836(44.5)	750(38.9)	697(34.8)
	Protestant	352(18.7)	457(23.7)	445(22.2)
	Muslim	642(34.2)	660(34.2)	786(39.2)
	Others	48(2.5)	61(3.2)	76(3.8)
Region				
	Tigray	135(7.2)	129(6.7)	152(7.6)
	Afar	18(1)	18(0.9)	20(1)
	Amhara	482(25.7)	446(23.1)	364(18.2)
	Oromia	691(36.8)	811(42)	881(44)
	Somali	78(4.2)	51(2.6)	76(3.8)
	Benishangul-Gumuz	16(0.9)	23(1.2)	21(1)
	SNNPR	408(21.7)	391(20.2)	419(20.9)
	Gambela	5(0.3)	8(0.4)	5(0.3)
	Harari	4(0.2)	5(0.3)	5(0.2)
	Addis Ababa	32(1.7)	43(2.2)	52(2.6)
	Dire Dawa	7(0.4)	7(0.4)	9(0.5)
Wealth index				
	Poorest	450(24)	441(22.9)	504(25.2)
	Poorer	399(21.2)	419(21.7)	396(19.8)
	Middle	381(20.3)	394(20.4)	450(22.4)
	Richer	345(18.4)	369(19.1)	366(18.3)
	Richest	302(16.1)	307(15.9)	288(14.4)

Table 1. Summary statistics for independent variables, EDHS 2005 – EDHS 2016 (continued)

Variable		EDHS 2005 N(%)‡	EDHS 2011 N(%)‡	EDHS 2016 N(%)‡
Maternal occupation				
	Not working	1295(69.1)	879(45.9)	1089(54.3)
	Working	578(30.9)	1036(54.1)	915(45.7)
Sex of child				
	Male	959(51.1)	1010(52.3)	926(46.2)
	Female	917(48.9)	920(47.7)	1078(53.8)
Exposure to media				
	Not exposed	1627(86.7)	1437(74.5)	1625(81.1)
	Exposed	250(13.3)	493(25.5)	379(18.9)
Use of antenatal care				
	No	1294(71.7)	1046(56.4)	712(37.4)
	yes	511(28.3)	810(43.6)	1193(62.6)
Place of delivery				
	Home	1743(92.9)	1681(87.1)	1271(63.4)
	Health Facility	134(7.1)	249(12.9)	733(36.6)
Place of Residence				
	Rural	1729(92.1)	1656(85.8)	1772(88.4)
	Urban	147(7.9)	274(14.2)	232(11.6)
Distance to health facility				
	big problem	1387(73.9)	1411(73.2)	1201(59.9)
	Not a big problem	489(26.1)	517(26.8)	803(40.1)

SNNPR: Southern nations and nationalities and peoples region ‡Sampling weights were applied

The CCs for measles vaccine uptake are displayed in Fig. 2. As shown in the figure, the line of equality dominates (falls above) all of the CCs for measles vaccine uptake. This indicates the existence of pro-rich inequalities in measles vaccine uptake in 2005, 2011 and 2016. The test of dominance between the CCs of measles vaccine uptake for 2005 (the earliest survey) and 2016 (the most recent survey) indicates non-dominance, thereby suggesting that the existence of socioeconomic inequalities in the uptake did not change significantly over time.

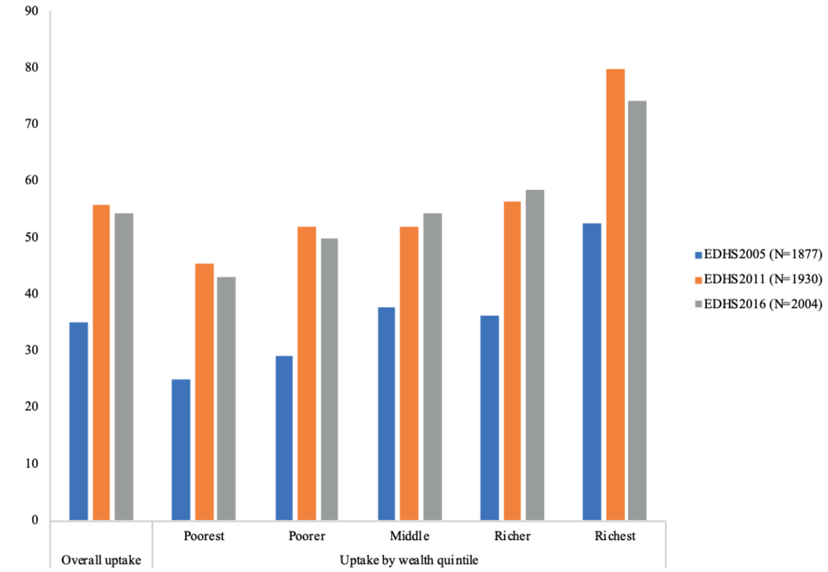

Fig. 1. Percentage of overall national measles vaccine uptake and uptake by wealth quintile among children aged 12 – 23 months in Ethiopia, EDHS 2005 – EDHS 2016.

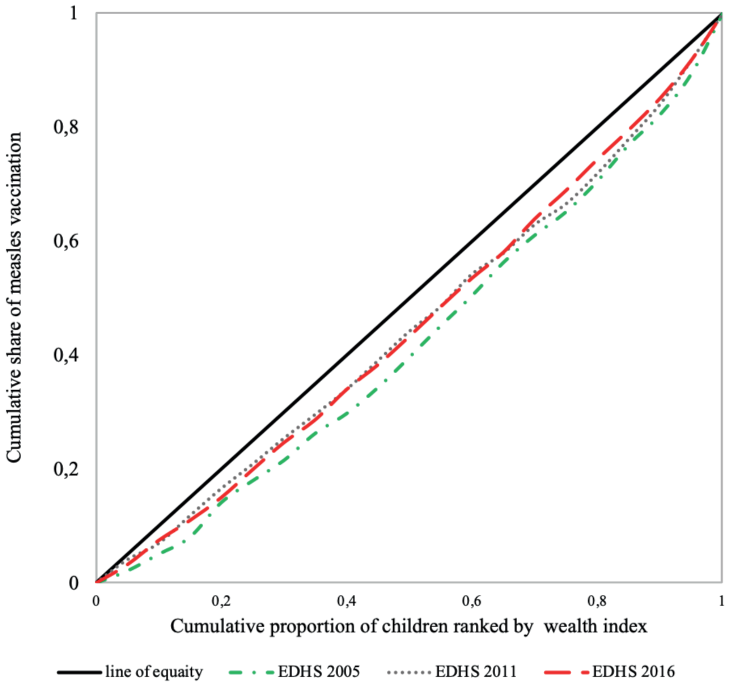

Fig 2. Concentration curves for measles vaccine uptake among children aged 12 – 23 months in Ethiopia, EDHS 2005 – EDHS 2016.

The ECIs for measles vaccine uptake among children aged 12–23 months are reported in Table 2. The CI for measles vaccine uptake was 0.202 (p<0.01) in 2005, 0,226 (p<0.01) in 2011 and 0.223 (p<0.01) in 2016. These results imply that there was persistent inequality in the uptake of measles vaccine to the advantage of children from relatively wealthy households across the study period, as already confirmed by the CC and dominance test.

The results of decomposition analysis are reported in Table 3. The CI, for instance, was positive for secondary and higher educational level, antenatal care use, and urban residence, thereby indicating that these variables were concentrated among people of higher socioeconomic status. The absolute contribution of each independent variable to inequality of measles vaccine uptake, as measured by ECI, is presented in the contribution column.

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Table 2. Erreygers' normalized concentration indices (ECIs) for measles vaccine uptake among children aged 12 – 23 months in Ethiopia, EDHS 2005 – EDHS 2016

Survey	ECI(SE)
EDHS 2005	0.202(0.0010)**
EDHS 2011	0.226(0.0012)**
EDHS 2016	0.223(0.0012)**

ECI: Erreygers' concentration index; BCG: Bacillus Calmette-Guérin; Bootstrapped standard errors are reported in parentheses; *, ** p-value <0.05 & <0.01, respectively

Table 3. Decomposition of socioeconomic related inequalities in measles vaccine uptake among children aged 12 – 23 months in Ethiopia, EDHS 2005 – EDHS 2016

Variables	2005			2011			2016		
	Coefficient	CI	Contribution	Coefficient	CI	Contribution	Coefficient	CI	Contribution
Mother's age (ref: 20-34)									
15-19	0.018(0.0620)	0.008(0.0022)**	0.000(0.0000)	-0.073(0.0647)	0.013(0.0024)**	0.000(0.0001)**	-0.011(0.0847)	-0.030(0.0025)**	0.000(0.0000)**
35-49	0.072(0.0356)*	-0.039(0.0011)**	-0.002(0.0001)**	0.010(0.0378)	-0.037(0.0012)**	0.000(0.0000)**	-0.025(0.0378)	-0.007(0.0012)**	0.000(0.0000)**
Maternal educational level (ref: No education)									
Primary	0.134(0.0406)**	0.293(0.0012)**	0.027(0.0003)**	0.073(0.0392)	0.184(0.0010)**	0.014(0.0003)**	0.035(0.0418)	0.102(0.0009)**	0.004(0.0002)**
Secondary and higher	0.046(0.0776)	0.812(0.0013)**	0.008(0.0004)**	0.083(0.0818)	0.757(0.0017)**	0.013(0.0004)**	0.040(0.0716)	0.752(0.0009)**	0.011(0.0006)**
Mother's employment status (working)	0.014(0.0319)	0.032(0.0008)**	0.001(0.0001)**	0.040(0.0324)	-0.008(0.0006)**	-0.001(0.0001)**	0.011(0.0352)	0.068(0.0007)**	0.001(0.0001)**
Religion (ref: orthodox)									
Protestant	-0.056(0.0529)	0.173(0.0010)**	-0.007(0.0002)**	-0.088(0.0569)	-0.049(0.0011)**	0.004(0.0001)**	-0.012(0.0612)	0.102(0.0011)**	-0.001(0.0002)**
Muslim	0.011(0.0430)	-0.202(0.0008)**	-0.003(0.0004)**	-0.032(0.0485)	-0.004(0.0008)**	0.000(0.0001)**	-0.084(0.0531)	-0.141(0.0008)**	0.018(0.0004)**
Others	-0.067(0.0969)	-0.055(0.0036)**	0.000(0.0000)**	0.048(0.0974)	-0.210(0.0032)**	-0.002(0.0001)**	0.131(0.1110)	-0.468(0.0033)**	-0.010(0.0003)**
Region (ref: Addis Ababa)									
Tigray	0.138(0.0792)	-0.161(0.0014)**	-0.007(0.0001)**	0.068(0.0631)	0.023(0.0015)**	0.000(0.0000)**	-0.008(0.0636)	0.032(0.0015)**	0.000(0.0000)*
Afar	-0.368(0.0792)**	-0.528(0.0025)**	0.007(0.0001)**	-0.320(0.0726)**	-0.352(0.0022)**	0.004(0.0000)**	-0.350(0.0776)**	-0.508(0.0023)**	0.007(0.0001)**
Amhara	-0.126(0.0785)	0.008(0.0010)**	-0.001(0.0001)**	-0.041(0.0739)	-0.084(0.0011)**	0.002(0.0002)**	-0.113(0.0777)	0.033(0.0013)**	-0.003(0.0001)**
Oromia	-0.177(0.0751)*	-0.034(0.0008)**	0.009(0.0003)**	-0.167(0.0641)**	0.041(0.0007)**	-0.011(0.0002)**	-0.228(0.0757)**	-0.026(0.0007)**	0.011(0.0004)**
Somali	-0.372(0.0798)**	-0.586(0.0022)**	0.036(0.0003)**	-0.179(0.0759)*	-0.064(0.0023)**	0.001(0.0000)**	-0.123(0.0814)	-0.503(0.0015)**	0.009(0.0002)**
Benishangul-Gumuz	-0.159(0.0819)	0.000(0.0018)**	0.000(0.0000)*	0.018(0.0690)	-0.086(0.0017)**	0.000(0.0000)**	-0.006(0.0808)	-0.240(0.0015)**	0.000(0.0000)**
SNNPR	-0.076(0.0811)	0.153(0.0009)	-0.010(0.0004)**	-0.041(0.0703)	-0.077(0.0012)**	0.003(0.0002)**	-0.164(0.0802)*	0.009(0.0011)**	-0.001(0.0002)**
Gambela	-0.205(0.0901)*	-0.072(0.0026)**	0.000(0.0000)**	-0.174(0.0800)*	-0.169(0.0025)**	0.000(0.0000)**	-0.160(0.0751)*	-0.014(0.0025)**	0.000(0.0000)**
Harari	-0.206(0.0756)**	0.559(0.0018)**	-0.001(0.0000)**	-0.073(0.0693)	0.478(0.0014)**	0.000(0.0000)**	-0.185(0.0739)*	0.332(0.0020)**	-0.001(0.0000)**
Dire Dawa	-0.047(0.0859)	0.345(0.0026)**	0.000(0.0000)**	0.080(0.0607)	0.362(0.0019)**	0.000(0.0000)**	0.123(0.0695)	0.285(0.0022)**	0.001(0.0000)**

Table 3. Decomposition of socioeconomic related inequalities in measles vaccine uptake among children aged 12 – 23 months in Ethiopia, EDHS 2005 – EDHS 2016 (continued)

Variables	2005			2011			2016		
	Coefficient	CI	Contribution	Coefficient	CI	Contribution	Coefficient	CI	Contribution
Female child	-0.025(0.0276)	-0.008(0.0006)**	0.000(0.0000)**	-0.028(0.0319)	0.010(0.0006)**	-0.001(0.0001)**	0.023(0.0330)	0.015(0.0006)**	0.001(0.0001)**
Antenatal care use	0.144(0.0362)**	0.289(0.0009)**	0.047(0.0004)**	0.225(0.0363)**	0.235(0.0007)**	0.092(0.0005)**	0.212(0.0404)**	0.107(0.0005)**	0.057(0.0004)**
Institutional delivery	0.155(0.0702)*	0.597(0.0018)**	0.026(0.0004)**	0.071(0.0678)	0.668(0.0011)**	0.024(0.0007)**	0.023(0.0390)	0.264(0.0008)**	0.008(0.0005)**
Urban residence	0.114(0.0773)	0.883(0.0004)**	0.031(0.0007)**	-0.002(0.0730)	0.784(0.0006)**	-0.001(0.0011)	0.015(0.0761)	0.740(0.0013)**	0.004(0.0008)**
Exposure to media	0.018(0.0491)	0.589(0.0010)**	0.006(0.0005)**	0.089(0.0415)*	0.344(0.0010)**	0.032(0.0005)**	0.082(0.0528)	0.511(0.0012)**	0.033(0.0007)**
Distance to health facility considered as not a big problem	0.039(0.0362)	0.243(0.0009)**	0.010(0.0003)**	0.097(0.0410)*	0.294(0.0009)**	0.031(0.0004)**	0.035(0.0380)	0.211(0.0007)**	0.013(0.0004)**
Unexplained			0.0235			0.019			0.061

CI: concentration index; SNNPR: Southern Nations Nationalities and Peoples Region; ECI: Erreygers' concentration index; Bootstrapped standard errors are reported in parentheses; *, ** p-value <0.05 & <0.01, respectively

The percentage contributions of various determinants to socioeconomic related inequalities in measles vaccine uptake are summarized in Fig. 3. The absolute values of the percentage contributions of specific determinants indicates the magnitude of their contributions to inequality. A positive value for a percentage contribution indicates that the determinant increased the inequality, while a negative value indicates the opposite. In 2005, antenatal care use (23.7%), maternal educational level (17.8%), region (17.3%), urban residence (15.4%), and institutional delivery (13.2%) were the most important contributors to the inequality of measles vaccine uptake. In 2011, antenatal care use (41.6%), exposure to media (14.65%), distance to a health facility (14.1%) and maternal educational level (12.4%) made noteworthy contributions to the inequality. Similarly, antenatal care use (26.0%) and exposure to media (14.6%) made a significant contributions in 2016. Although they were statistically significant in most of the times periods, several factors (e.g., maternal occupation and female sex of the child) made the smallest contributions to the observed inequalities.

The decomposition analysis was replicated using partial effects of probit regression, and the results appeared to be robust. For the sake of brevity, these results are not shown here.

DISCUSSION

In this study, we investigated the pattern of socioeconomic inequality in measles vaccine uptake in Ethiopia between 2005 and 2016 using data from the EDHS. According to our analysis, the national average for measles vaccine uptake increased from 34.9% in 2005 to 54.3% in 2016. The level of coverage was low, however, in comparison to countries that have declared the elimination of measles by maintaining a high level of measles vaccination uptake (>95%) [6]. Previous studies have also revealed that low measles vaccine uptake is associated with measles outbreaks [11,30]. This suggests the need to increase the uptake of measles vaccine in order to contain the ongoing measles outbreaks in Ethiopia.

Despite the increasing trend observed in national measles vaccine uptake in Ethiopia, our study reveals persistent socioeconomic inequalities in such uptake. This finding highlights the fact that children from the poorest households lagged behind those from relatively wealthy households in terms of measles vaccination. A previous study conducted in Ethiopia also identifies pro-rich inequality in measles vaccine uptake between 2000 and 2011 [20]. Another study involving other developing countries has also demonstrated that improving the overall level of national measles vaccine uptake

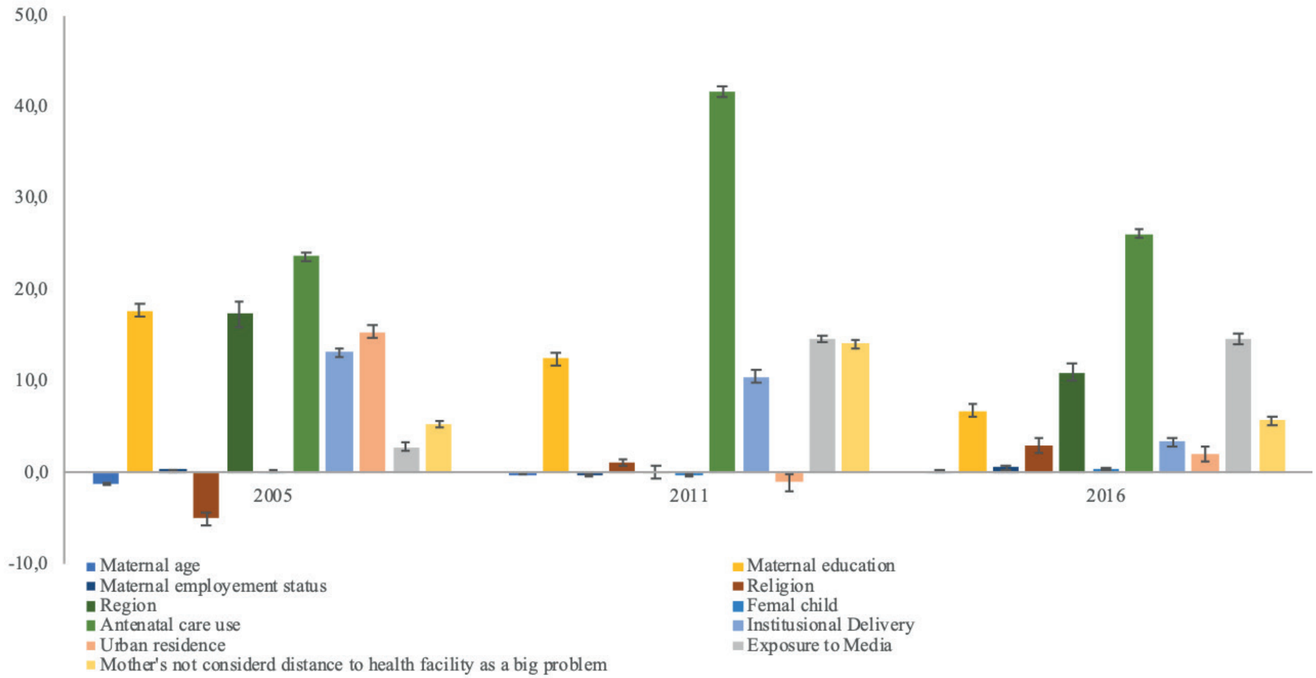

Fig. 3. Percentage contributions of independent variables to socioeconomic related inequality in measles vaccine uptake among children aged 12 – 23 months in Ethiopia, EDHS 2005-2016 (Notes: The percentage contribution of a variable is the sum of the percentage contributions of each category of the variables. The error bar shows a 95% confidence interval).

does not necessarily result in a decrease in inequality [31]. In contrast to our findings, a study conducted in Vietnam reports a declining trend for socioeconomic inequalities in measles vaccine uptake [32].

In countries like Ethiopia, in which the majority of households are entirely dependent on labor-intensive subsistence agriculture for their livelihood and in which the household members spend most of their time on agricultural activities, the costs of travel and waiting time in terms of forgone income in relation to vaccinations are enormous. As a result, families might not be eager to vaccinate their children, particularly during high season. In other cases, they might withdraw from the immunization program before completing the schedule. Previous studies in Ethiopia have identified the heavy workload of mothers as one cause of incomplete immunization for their children [33,34].

As revealed by the decomposition analysis of socioeconomic inequalities, maternal educational level, antenatal care use, institutional delivery and exposure to media consistently contributed to the inequality observed in measles vaccine uptake across the study period. The considerable contributions of education might have been due to the role that education plays in improving maternal health literacy and healthcare-utilization behavior. In addition, educated mothers might also be more confident and better in communication, thereby facilitating their interactions with health care providers, and increasing the uptake of immunization among their children. Mothers with higher levels of education are also more likely adhere to the immunization schedule, with a lower dropout rate. Various studies have highlighted the positive role of maternal education on childhood vaccination [35–37]. The contribution of antenatal care utilization and institutional delivery to the inequality observed might be associated with their effects of these factors on raising maternal awareness and knowledge concerning childhood immunization programs. Comparable results are reported in a study conducted in low and middle-income countries [38].

According to our findings, over time, exposure to media has become an important determinant of inequalities in measles vaccine uptake. This might be because mothers exposed to mass media are better informed about the importance of immunization. In Ethiopia, mass media (e.g., community radio) has expanded rapidly throughout the country since 2005. Poor people have not benefitted from this development, however, as most of them are not active listeners, due to the lack of radio receivers and television sets in their households [39]. Research in Burkina Faso indicates that media campaigns focusing on child health resulted in a significant increase in health-seeking behaviors and a decrease in mortality among children younger than five years of age [40].

According to our results, the contribution of urban residence to the inequalities observed declined over time. This implies that the uptake of measles vaccine improved more over time in rural areas than it did in urban areas. This finding might have been due to the role of the Health Extension Program (HEP). The HEP has been implemented primarily in rural parts of the country since 2003, with the goal of improving access to and utilization of primary health care services, including childhood and maternal vaccination [41,42]. Studies have indicated that the HEP is making substantial contributions to the improvement of maternal and child health in Ethiopia [43,44].

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The findings of this study have important policy implications. They suggest that assessing the performance of immunization programs only in terms of the overall national vaccine uptake might be misleading, as such statistics tend to obscure within-country inequalities. Higher levels of national vaccine uptake can be achieved by improving the uptake only among the affluent and easily accessible segments of the population, while the poorest and hardest-to-reach children—who are at the greatest risk of vaccine-preventable diseases—might remain unimmunized. In their effort to accelerate universal immunization coverage, therefore, countries should monitor their progress in terms of equity [45,46]. The results of this study also reveal several drivers of the inequalities observed that could be targeted in order address potential enablers of and barriers to vaccine uptake, thereby minimizing the disparities and ensuring that disadvantaged populations are not left behind by working on potential. In Ethiopia, certain policy measures including Reach Every District (RED), HEP and Enhanced Routine Immunization Activities have reportedly to played a role in improving the national immunization coverage [47]. By taking equity goals into consideration, these strategies can go even further toward increasing vaccine uptake among the most vulnerable groups. Other more sensitive and context-specific policy actions that reach the disadvantaged households should also be sought.

Our study is obviously subject to a number of limitations. First, it was not possible to establish any causal inferences as the data were obtained according to a cross-sectional study design. Second, when vaccination cards were unavailable, children's vaccination histories were determined according to the self-reports of mothers. This might have introduced bias, possibly resulting in underestimation or overestimation of the vaccine uptake. Third, the contributions of supply-side factors to the inequalities were not investigated, as the dataset did not provide such information. Additional studies are needed in order to address these factors.

CONCLUSIONS

Despite the improvement in national measles vaccine uptake between 2005 and 2016, socioeconomic inequalities in the uptake have persisted over time in Ethiopia. It is therefore important to design more effective strategies in order to sustain the progress and address the issues of socioeconomic inequality issues by reaching out to disadvantaged households.

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Part II:

Health economics of human papillomavirus vaccine