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ORIGINAL RESEARCH ARTICLE

Determinants and Regional Differences in Under-Five Mortality in Ethiopia Using Multilevel Count Analysis

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Abstract

Under-five mortality is a leading indicator of child health and overall development. The under-five mortality rate is the probability of a child born in a specified year dying before reaching the age of five. The aim of this study was to investigate the determinants and regional differences in under-five mortality in Ethiopia. The data for this study were obtained from the EDHS 2016, which was a nationally representative survey of children in the age group 0-5 years, and multi-level count regression analysis was used to analyze the data. 42.7% of the mothers have faced any at least one under five child death (U5CD) in their lifetime and 1.8% of them experienced at least five U5CD. The findings revealed that toilet facility, birth order, place of delivery, place of residence, source of drinking water, family size and sex of the household head were predictors of under-five mortality. The incidence rates are high in Amhara, Dire Dawa and SNNP, while lower rates are estimated in Addis Ababa, Harari and Oromia. The government and other concerned bodies should focus on the realization of access to safe water for all households and the community as a whole in Ethiopia, in order to minimize the under-five child mortality. Toilet facility plays an important role in child survival. The multilevel analysis further showed that there were substantial under-five death variations per mother among regions in Ethiopia, and were significant (random intercept variance = $\boldsymbol{\sigma}^2_{\boldsymbol{u0}}$ = 0.313, P- value <0.001).

Keywords: U5CD, Poisson, Multilevel, Risk Factor

Introduction

Under-five year child death (U5CD) is the probability of dying between birth and the fifth birthday. Information on infant and child mortality is relevant to a demographic assessment of the population, and is an important indicator of a country's socioeconomic development and quality of life (CSA, 2016). Demographers have for a long time been interested in the study of mortality, which is one of the components of population change. Infant and child mortality are among the best indicators of socio-economic development because a society's life expectancy at birth is determined by the survival chances of infants and childrenSnijder, 2011). The largest number of newly-born deaths occurred in Southern Asia 39%, followed by sub-Saharan Africa 38%. Five countries accounted for half of all newly-born deaths: India, Pakistan, Nigeria, the Democratic Republic of Congo, and Ethiopia (WHO, 2017).

A study was carried out to assess the social determinants of under-five mortality in Ethiopia. There was a higher-load of under-five mortality (incidence rate ratio of 24.95 per

1000-person years) with the highest risk of under five-mortality (Gizaw, 2015). The study conducted to identify the determinants of under-five mortality in Ethiopia using EDHS's (2011) data which indicated that nationally, 34.9% of mothers had faced at least one under-five death (Berhie and Yitaw, 2017). The study considered 11654 participants, from which 846 (7.26%) were death, where as 10808 (92.74%) were alive at the date of the survey (Bedada, 2017).

The median of infant mortality in Tanzanian zones between the years 1992 to 2010 was 77 deaths per 1000 live-births within the given interquartile range. In addition, the median of under-five death rate for all zones was 130 deaths per 1000 live births within the given range (Byaro and Musonda, 2016). EDHS 2016 results show that under-5 mortality rate for the 5 years before the survey was 67 deaths per 1,000 live births. In other words, in Ethiopia from 15 children 1 dies before reaching his/her fifth birthday (CSA, 2016).

Ethiopia was losing productive man-power because of a lot of problems. Childhood death was one of these problems, so as a researcher it is needed to identify those potential factors and the regional differences of U5CD in order to reduce this mortality. Thus, this study attempts to address the regional variation of under-five mortality and explore the determinants of infant and child death taking into consideration various health, socio-economic and environmental factors such as mothers' age, mothers education, place of residence, economic status of the household, etc. Most studies have not considered the regional (second level) variations that can possibly affect the response (number of U5CD that each mother has experienced in her life time).

Methods

Data

The source of data used in this study was the 2016 EDHS data conducted in Ethiopia as part of the worldwide demographic and health survey project. The 2016 EDHS sample was stratified and selected in two stages. Each region was stratified into urban and rural areas, yielding 21 sampling strata. In the first stage, 645 enumeration areas (202 in urban areas and 443 in rural areas) were selected. In the second stage of selection, a fixed number of 28 households per cluster were selected with an equal probability systematic selection from the newly created household listing. All women aged 15–49 and all men aged 15–59 who were either permanent residents of the selected households or visitors who stayed in the household the night before the survey were eligible to be interviewed (CSA, 2016).

Variables in the Study

The response variable of this study was the number of deaths of children aged less than five years old that each mother has experienced in their lifetime. Various independent variables such as mother's literacy status, age at first birth, child's characteristics, birth interval, sex of the child and type of birth (twines), husband characteristics, educational status of husband, household characteristics, household wealth (economic status), region, residence, family size, availability of safe drinking water, type of cooking material, and availability of toilet facility were considered in this study.

Poisson regression

Count event is the number of times a given event occurred in a specified place and time. The count dependent variable has non-negative integer responses to be explained in terms of set of covariance (X). Unlike the classical regression model, the count response variable is discrete in nature with a distribution of probability mass at nonnegative integer values only. Counts of rare events, ordered and nominal categorical data are usually violating the assumption of normality. When the response variables are non-normal, usually the data are normalized using non-linear transformation method to apply robust estimation methods. Then, the resulting data can be preferably analyzed using the generalized linear model (Cameron and Trivedi, 1998).

Poisson Log linear Models

The Poisson distribution has a positive mean μ. Although a GLM can model a positive mean using the identity link, it is more common to model the log of the mean. The log mean is the natural parameter for the Poisson distribution, and the log link is the canonical link for a Poisson GLM. A Poisson log linear GLM assumes a Poisson distribution for Y and uses the log link (Agresti, 2002). The Poisson log linear model with explanatory variable X is $\ln(\mu_i) = \eta_i = x_i\beta$

In the general Poisson regression model, we think of μ_i as the expected number of under five-child death from the i^{th} mother and the total number of children ever born from the i^{th} mother is N_i. This means the parameter will depend on the population size and the total number of children ever born from individual mothers. Thus, the distribution of Yi can be written as: $\mathbf{Y_i \sim poisson\ (N_i\mu_i)}$.

Thus, the GLM with an offset is given by:

$$\log \mu_i = \log Ni + x_i\beta$$

Multilevel generalized linear model

The multilevel generalized model has been described by Wong and Mason (Mislevy and Bock, 1989; Goldstein, 1999). In the generalized multilevel models, the multilevel structures appear in the linear regression equation of the generalized linear model. The full model equations for the two-level (regional variation) Poisson regression with i^{th} individual mothers are nested within the jth region. Using the logarithmic transformation, the level-1 (individual observation) model with $\boldsymbol{k}$ explanatory variables $\boldsymbol{X1}$, …, $\boldsymbol{Xk}$ can be written as:

$$\ln(\mu_{ij}) = \ln(N_{ij}) + x_{ij}\beta + \sum_{p=0}^{k} \mu_{pj} x_{pij}$$

Under this model we used the random intercept and random coefficients model.

$$\ln(\mu_{ij}) = \ln(N_{ij}) + \sum_{p=1}^{k} \beta_{0j} + \beta_{pj} x_{pij}$$

Multilevel Poisson model

Let us define the Poisson multilevel model using $\boldsymbol{\mu_{ij}}$ be the expected number of under-five child death. The log link function for the Poisson model with random coefficients is:

$$\ln(\mu_{ij}) = \eta_{ij} = x_{ij}\beta + \sum_{p=0}^{k} \mu_{pj} x_{pij}$$

If we include the offset, the model will be written as:

$$\ln(\mu_{ij}) = \ln(N_{ij}) + x_{ij}\beta + \sum_{p=0}^{k} \mu_{pj} x_{pij}$$

The variances and covariance of the level-two random effects are denoted by:

$$\operatorname{cov}(\mu_{pj}, \mu_{sj}) = \sigma_{\mu ps} \qquad p = 0, 1, 2 \text{ …., } k$$

$$p(Y_{ij} = y_{ij}) = \frac{\exp^{\mu_{ij}} \mu_{ij}^{\ y_{ij}}}{y_{ij}!} \qquad p = 0, 1, 2, \text{ …}k \text{ and } p \neq s$$

The probability distribution of Y_{ij} is Poisson distribution, so the probability that Y_{ij} takes the specific value y_{ij} is:

$$\operatorname{var}(\mu_{pj}) = \sigma^2_{\ \mu p} \quad y_{ij} = \text{o}, 1$$

With the usual property that $E\ (Yij) = var\ (Yij) = \mu_{ij}$ which equals to exp($\boldsymbol{\eta ij}$). For any given region, the exponential of each element which is related to an individual covariate of the fixed effects of vector $\boldsymbol{\beta}$ and it gives the multiplicative effect on the mean number of events $\boldsymbol{\mu ij}$ for a unit increase in the corresponding covariate $\boldsymbol{Xpij}$, assuming that all the other covariates are held constant. Further, the covariance between the random intercept and the random slope, $\boldsymbol{C}$ov ($\boldsymbol{\mu_{0j}}$, $\boldsymbol{\mu_{pj}}$), is used to calculate the correlation between the intercept and the corresponding slope.

$$\operatorname{cov}(\beta_{0j}.\beta_{pj}) = \operatorname{cov}(\gamma_0 + \mu_{0j}.\gamma_p + \mu_{pj}) = \sigma_{\mu op}$$

Results

The distribution of the number of under-five mortality per mother and the summary of region by explanatory variables assessed in this section:

Table 1. number of U5CD that each mother has experienced, EDHS, 2016

No of U5CD	Frequency	Percent	Cumulative Percent
0	23722	57.3	57.3
1	9113	22.0	79.3
2	4651	11.2	90.6
3	2168	5.2	95.8
4	991	2.4	98.2
≥ 5	747	1.8	100.0
Total	**41392**	**100**	

Table 1 shows that 57.3% of mothers have not faced any U5CD in their lifetime and 1.8% of them experienced at least five U5CD.

Eighteen and half percent of mothers live in urban areas while 81.5% of them live in rural areas. About 87.9% of women living in rural areas have lost at least one child in their lifetime. 82.5% of mothers who have no education have lost at least one child in their lifetime, while this figure for mothers with secondary and higher education is only 2.9%. All regions of Ethiopia varied in women's level of educational achievement. For instance, Addis Ababa, Gaambela, Harari and Dire-dawa administrative city had the highest proportion of women with secondary and higher education while the other regions account for only less than 21.5% of this category. The worst level of women education was observed in Somalia and Afar regions. At the national level, only 6.8% of women had secondary and higher education and the proportion of women who had no education constitute 73.1%. An economic indicator i.e. wealth index, reveals that Afar, Somali and Gambela regions of Ethiopia have about 93.5%, 86.5% and 74% poor mothers respectively, but Addis Ababa has only 5.2%. Wealth can have a potential effect on child survival in case a child faces health problem. A wealthy woman affords to take a sick child to a better health care center and she is even able to take extra precautions to protect her child from any type of injury and disease. More than 97% of women from Addis Ababa administrative city had toilet facility. The minimum percentage of women that gave their first birth before they become 20 years old was 55.9 percent. The regional variation, 85.6% of women from Afar gave their first birth before they reach age 20 which was followed by Amhara (84.3%). The result indicated that nationally 42.7% of mothers have lost at least one under-five child in their lifetime.

Turning first to the main effects model or model selection, the result revealed the Poisson regression fit statistic. For the Poisson model both the AIC and BIC are 4153.384 and 4274.939. So, there was no evidence to show over dispersion and the researcher used Poisson regression model for the analysis of this research.

Table 2. Poisson Regression model for under-five mortality by region of residence and for selected independent variables, 2016, EDHS.

		Models											
		I			II			III			IV		
Variables		B	SE(β)	Exp (β)	B	SE(β)	Exp(β)	B	SE(β)	Exp (β)	B	SE (β)	Exp (β)
Intercept		-0.94	0.04	0.39	-0.26	0.05	0.77	-1.28	0.03	0.28	-0.41	0.06	0.66
Sex of child	male (ref)										-0.01	0.02	0.99
	Female				-0.01	0.02	0.99						
House hold Sex	male(ref)												
	Female				-0.06	0.03	0.94				-0.060	0.03	0.94
Age at first birth	<20 (ref)												
	≥20				-0.21	0.24	0.81				-0.20	0.02	0.819
Resi-dence	Urban(ref)												
	Rural							0.33	0.03	1.39	0.190	0.04	1.21
Region	Tigray(ref)												
	Afar	0.27	0.34	1.03	0.09	0.04	1.09	0.25	0.03	1.28	0.100	0.04	1.11
	Amhara	0.21	0.32	1.23	0.15	0.04	1.16	0.18	0.03	1.19	0.150	0.04	1.16
	Oromiya	0.07	0.03	1.07	-0.004	0.04	0.99	0.04	0.03	1.04	-0.010	0.04	0.99
	Somali	0.17	0.03	1.18	-0.003	0.04	0.99	0.17	0.03	1.18	0.010	0.04	1.01
	Benshangul	0.11	0.03	1.12	0.01	0.04	1.01	0.07	0.04	1.07	0.010	0.04	1.01
	SNNP	0.18	0.03	1.20	0.14	0.04	1.15	0.15	0.03	1.16	0.130	0.04	1.14
	Gambela	-0.05	0.04	0.95	0.06	0.05	1.06	-0.4	0.04	0.67	0.050	0.05	1.05
	Harere	-0.16	0.05	085	-0.11	0.05	0.89	-0.8	0.05	0.45	-0.090	0.05	0.91
	Addisababa	-0.95	0.07	0.39	-0.63	0.09	0.53	-0.61	0.07	0.54	-0.520	0.10	0.59
	Dire dawa	0.07	0.04	1.07	0.07	0.05	1.07	0.22	0.04	1.25	0.120	0.05	1.14

Table 2. *Continued*

		Models											
		I			II			III			IV		
Variables		B	SE (β)	Exp (β)	B	SE(β)	Exp (β)	B	SE(β)	Exp (β)	B	SE (β)	Exp (β)
Education level of mother	No education(ref)												
	Primary				-0.23	0.03	0.79				-0.220	0.03	0.8
	Secondary &higher				-0.30	0.06	0.74				-0.250	0.07	0.78
Family Size	Family size				-0.05	0.01	0.95				-0.050	0.004	0.95
Place of delivery	Home(ref)												
	Gov't Health center										-0.160	0.05	0.85
	Private Health center										0.230	0.15	1.26
Contraceptive	user(ref)												
	Non-user				0.21	0.02	1.23				0.20	0.02	1.22
Source of drinking water	Piped(ref)												
	Not piped							0.08	0.02	1.08	0.270	0.02	1.31
Toilet facility	There is toilet (ref)												
	There is no toilet							0.07	0.08	1.07	0.247	0.16	1.28
Deviance		29476.5			18731.94			29221.29			18706.69		

Table 2 showed the result of Poisson regression. The results suggest significant regional variations in child mortality in Ethiopia. Model IV shows that the risk of child mortality was 1.11 times higher among children born to mothers in Afar region as compared to children born in Tigray. Model IV further suggests that the risk of child mortality in Amhara region was 16% higher than the risk in Tigray. Addis Ababa administrative city is found to have the lower risk of under five-child mortality per mother and was 41% lower than Tigray. This model also suggests that the risk of under five-child mortality was 14 % higher among children born to mothers in SNNP and Dire Dawa as compared to Tigray.

Result in Model IV revealed that children of mothers' who had access to piped water had about 31% lower risk of mortality compared to children of mother who have no access to piped water. Children born from mothers who do not have toilet had about 28% higher risk compared to children born from mothers who have toilet facility. Children born from mothers whose age at first birth was greater than or equal to 20 had significantly about 18% lower mortality compared to those born from mothers whose age at first birth is less than 20 (see Table 2).

Multilevel analysis

Fig. 1 shows the plot of the mean of U5CD for all regions versus the selected predictor, place of residence. It can be seen in the figure that the regions have different intercept and slope, suggesting that the effect of place of residence varies from one region to another.

Generally, the lines in Figs. 1 and 2 have different intercepts and slopes, and the steeper the slope the stronger is the relationship between place of residence and U5CD per mother (see Fig. 1) or contraceptive and U5CD per mother (see Fig. 2).

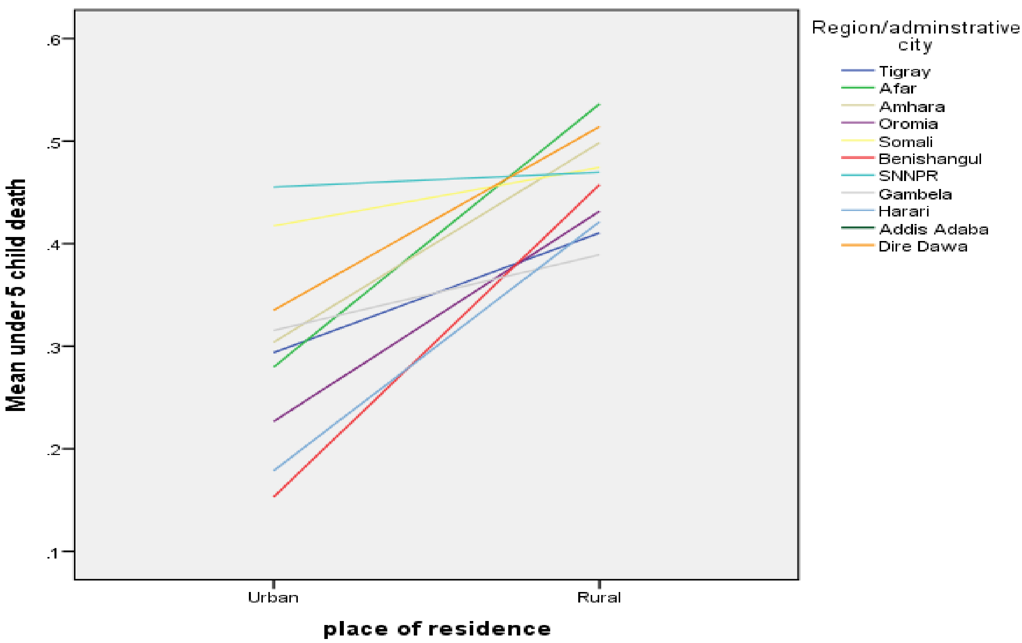

Figure 1. Plot of the mean of U5CD versus place of residence, EDHS, 2016.

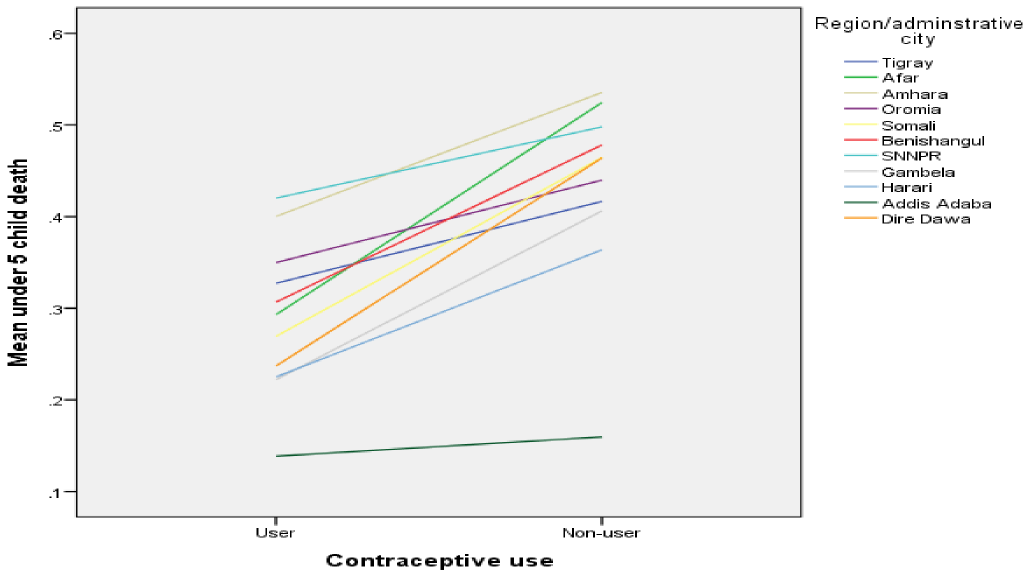

Figure 2. Plot of mean of U5CD versus contraceptive use, EDHS, 2016

The model with random intercept and random coefficients was found to be a best fit in explaining regional differences in under-five death per mother. The results of fitted random intercept and random coefficient model are given in Table 3

Table 3. Results of a Poisson multilevel model with random intercept and random coefficients for source of drinking water and toilet facility, EDHS, 2016.

	U5CD	B	Std. Err(β)	xp(β)	P>z
Variables	Constant(β_0)	-1.169	0.088	0.311	P<0.001
Sex	Male(ref)				
	Female	-0.077	0.061	0.210	P<0.001
Age at first birth	<20(ref)				
	≥20	-0.247	0.074	0.781	P<0.01
Place of residence	Urban(ref)				
	Rural	0.101	0.056	1.106	0.074
Mother's Education level	No education(ref)				
	Primary	-0.298	0.036	0.742	P<0.001
	Secondary & above	-0.616	0.077	0.540	P<0.001
Family size	Family size	0.046	0.006	1.042	P<0.001
Type of birth	Single(ref)				
	Multiple	0.352	0.067	1.422	P<0.001
Contraceptive use	Use(ref)				
	Not use	0.164	0.032	1.177	P<0.001
Drinking water Source	Piped				
	Not piped	0.169	0.067	1.184	P<0.05
Toilet facility	Have toilet(ref)				
	No toilet	0.176	0.092	1.192	P<0.01
Random effect parameters	Region:effects				
	Sd drinking water	0.107	0.039	1.113	P<0.01
	Sd toilet facility	0.035	0.045	1.049	P<0.05
	Sd constant	0.047	0.088	1.049	P<0.001

The results of fitted random intercept and random coefficient model are given in Table 3. According to the table, the overall regional variance constant term, and the variance term for drinking water and toilet facility was found to be significant. The fixed effect of source of drinking water supply of the household, educational level of mother, family size, sex, age at first birth, type of birth (twines) and contraceptive use are significant (p-values<0.05). Under five child death for age at first birth above 20 years 21.9% less likely than age at first birth below 20years. Child mortality for educational levels primary and Secondary and above are 25.8% and 46% less likely than mothers no educational, respectively. The mortality of child increases when the number of family size increased. When the number of family increased by one; the mortality increased by 4.2%. The death percentage of children's whose mother does not use piped water was 18.4% higher as compared to use piped water. U5CD for mothers do not have toilet facility 19.2% higher than mothers do have toilet facility. Children of mothers who do not use contraceptive have 17.7% more likely to die than those who uses contraceptive. On the other hand, mothers who give multiple births have 42.2% chance to lose their child under-five years of age than those who gave single birth.

Discussion

The study showed that large family size significantly associated with increasing the risk of child mortality relative to small family size. This means as family size increases, the risk of child mortality also increases. This is because large households are more likely to share facilities. This result is supported by other previous researches (Henok, 2009; Zerihune, 2016). Toilet facility is a high-risk factor for child mortality. Households having availability of toilet facility has less risk of child mortality than households without toilet facility. Households who do not have toilet were 19.2 % more likely to have their child died. That means households with no access to improved toilets facility have high risk of child mortality. This finding was consistent with other studies conducted in the previous time on the same issues (Henok, 2009; Zerihune, 2016).

Under-five child mortality risk increases as birth order increases. This result was supported by the studies done in the previous period (Muluye and Wencheko, 2012; Mekonne, 2011). Place of delivery was found to be a significant predictor of under-five mortality. This finding was inconsistent with a previous study done on this issue (Berhie and Yirtaw, 2017). The study showed that under five years old children living in rural areas have a 10.6% higher risk of mortality as compared to children living in urban area. This result is supported by other researchers; high mortality was observed in rural areas than children living in urban areas (Zerihun, 2016). Children in households with accesses to unprotected water are 18.4% at high risk of dying before their fifth birth day than those children in households having accesses to protected water. Children in households with access to piped drinking water are less risk of child mortality. This was consistent with other findings done in this area (Zerihune, 2016; Kumar and Gemechis, 2010).

Conclusion

Before the analysis of data using the Poisson approach, the basic assumption of the Poisson model, that is, equality of the mean and variance of the number of under-five death from individual mother was tested. And the deviance for poison is 1917.384 small, the results indicated that there was no over dispersion. Therefore, the final models are fit as Poisson linear model with a log link to accommodate the count nature of the response variable. In Ethiopia, Amhara, SNNP, Afar region and Dire Dawa administrative city registered the highest under-five mortality risks. We showed that there is a significant variation of under-five mortality between regions. Because of these potential differences, under-five child mortality exhibits a significant variation among regions of Ethiopia. In Ethiopia; Amhara, SNNP, Afar regions; and Dire Dawa administrative city registered the highest under-five mortality risks. Therefore, according to the results, toilet facility and source of drinking water are important environmental predictors of under-five child mortality, that is, mortality rate decreases with increase in the facility of toilet and with increased access to piped water.

Effective programs to reduce early childbearing of women should be implemented so as to decrease under-five child mortality. Under-five mortality differentials per mother among regions are significant. Future studies should to be done in ardor to identify risk factors of U5CD separately for each region of Ethiopia.

Ethical Approval

Ethical clearance was obtained from the College of Natural and Computational Sciences, University of Gondar and a formal letter of cooperation was written for Central Statistical Agenesis.

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Acronyms

AIC = Akaike's Information Criterion
CSA = Central Statistical Agency
DHS = Demographic and Health Survey
EDHS = Ethiopian Demographic and Health Survey
U5CD = Under-Five Child Death
SNNP = South Nation Nationality Peoples

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