
Determinants of Under-five Deaths in Urban Parts of Ethiopia

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Abstract: Introduction: Under-five mortality rate is defined as the probability (expressed as a rate per 1 000 live births) of a child born in a specified year dying before reaching the age of five years subject to current age-specific mortality rates (UNICEF 2008). Objects: The objective of this study was to identify determinants of under-five mortality in urban parts of Ethiopia using the 2011 EDHS data. Methods: To achieve the objective of this study descriptive statistics and count regression models were used for data analysis using socio-economic, demographic and environmental related variables as explanatory variables and the number of under-five deaths per mother as the response variables. Results: Information on the number of deaths of under-five children obtained from a total of 1,807 women in the urban parts of Ethiopia was studied. From these, 328 women experienced 513 under-five deaths. From these, 328 women experienced 513 under-five deaths. Conversely, 81.8% of the women in urban areas never experienced under-5 death of their children. Nevertheless, 12%, 3.6%, 1.6%, 0.6%, 0.2%, 0.1% and 0.1% of them lost 1, 2, 3, 4, 5, 6 and 7 of their under-five deaths, respectively. Conclusion: Factors influencing the number of under-five deaths have been identified. Mother's level of education, age of mothers at the first birth, toilet facility and work/employment status of mothers were found to be statistically significant with the number of under-five deaths per mothers in urban parts of Ethiopia.

Keyword: Urban, Under Five Mortality, Count Regression Model

1. Introduction

Under-five mortality rate is defined as the probability (expressed as a rate per 1 000 live births) of a child born in a specified year dying before reaching the age of five years subject to current age-specific mortality rates [1]. It has several advantages as a barometer of child well-being in general and child health in particular. First, it measures an outcome of the development process rather than an input, such as per capita calorie availability or the number of doctors per 1,000 population – all of which are means to an end. Second, the U5MR is known to be the result of a wide variety of inputs: the nutritional status and the health knowledge of mothers; the level of immunization and oral rehydration therapy; the availability of maternal and child health services (including prenatal care); income and food availability in the family; the availability of safe drinking water and

basic sanitation; and the overall safety of the child's environment, among other factors. Third, the U5MR is less susceptible to the fallacy of the average than, for example, per capita gross national income (GNI per capita). This is because the natural scale does not allow the children of the rich to be 1,000 times as likely to survive, even if the human-made scale does permit them to have 1,000 times as much income. In other words, it is much more difficult for a wealthy minority to affect a nation's U5MR, and it therefore presents a more accurate, if far from perfect, picture of the health status of the majority of children (and of society as a whole).

Despite the fact that a number of researchers have studied the risk factors of under-five mortality in Ethiopia, the majority of them studied the risk factors at national level. Such studies have overlooked an important point for policy makers as the findings at national level may not demonstrate the exact situation at urban areas. Under-five death is

showing a declining trend over the last decades. According to [2], report the level of under-five mortality in urban area is 83 deaths per 1000 live births.

Logistic regression cannot provide sufficient information for studying the pattern of multiple child deaths. Therefore, we can develop and compare count regression models for the number of under-five deaths and discuss how they can enhance our understanding of the risk factors of under-five deaths. The general objective of this study is to identify the risk factors of under-five mortality in Urban Ethiopia.

2. Methods

2.1. Source of Data

The source of the data in this study is the 2011 Ethiopia Demographic and Health Survey (EDHS). SPSS version 23 and STATA version 14 were used as tools of analysis.

2.2. Variables in the Study

Detail description and coding of the demographic, socioeconomic, and environmental factors to under-five mortality is presented in Tables 1, 2, and 3 respectively.

2.3. Data Analysis

In this study, the variable of interest is a count variable. Count data is non negative, integer, non-normal and etc. For this study four count regression models.

2.3.1. Poisson Regression Model

In the poisson regression model, mean = variance. Let Y_i represent counts of events occurring in a given time or exposure periods with rate μ_i . Y_i are Poisson random variables which the p. m. f. is characterized by

$$P(Y_i=y_i, \mu) = \frac{e^{-\mu_i} \mu_i^{y_i}}{y_i!}, \mu_i > 0, i=1, 2, \dots, n \text{ and } y_i = 0, 1, 2, \dots$$

where, y_i denotes the value of an event count outcome variable occurring in a given time or exposure periods with mean parameter μ_i .

The log-likelihood function is

$$P(y_i; \mu_i, \alpha) = \frac{\Gamma(y_i+1/\alpha)}{y_i! \Gamma(1/\alpha)} (1 + \alpha \mu_i)^{-\frac{1}{\alpha}} \left(1 + \frac{1}{\alpha \mu_i}\right)^{-y_i}, y_i \geq 0 \text{ and } \alpha > 0.$$

where, α shows the level of overdispersion and $\Gamma(\cdot)$ is the gamma function

2.3.3. Zero-inflated Poisson Regression Model

The Zero-inflated Poisson regression study the relationship between dependent and independent variable(s) when there are many zeros value in the dependent variable, where the relationship is the mixture between Poisson model and Logistic model. The ZIP regression model is [4],

$$\ell = \text{Log}(L(\beta)) = \sum_{i=1}^n [y_i \ln \mu_i - \mu_i - \ln y_i!]$$

There are two basic criteria commonly used to check the presence of overdispersion:

1. Deviance, $D(y, \hat{\mu})$, is given by

$$D(y, \hat{\mu}) = 2 \times \sum_{i=1}^n \{y_i \ln \left(\frac{y_i}{\hat{\mu}_i}\right) - (y_i - \hat{\mu}_i)\}$$

where, y is the number of events, n is the number of observations and $\hat{\mu}_i$ is the fitted Poisson mean.

2. Pearson chi-square test, x^2 is also given by

$$x^2 = \sum_{i=1}^n \frac{(y_i - \hat{\mu}_i)^2}{\hat{\mu}_i}$$

Over-dispersion may be a result of higher occurrence of zero counts and subject heterogeneity. If the model fits the data, both deviance and Pearson Chi-square statistics divided by the degrees of freedom are approximately equal to one. Values greater than one indicate the variance is an over-dispersion, while values smaller than one indicate an under-dispersion.

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 children ever born from the i^{th} mother is N_i . This means parameter will depend on the population size and the total number of children ever born from the individual mother. Thus the distribution of Y_i can be written as:

$$Y_i \sim \text{poisson}(N_i \mu_i)$$

where N_i is the total fertility rate of i^{th} mother and

$$\mu_i = \exp(X_i^T \beta)$$

The logarithm of the children ever born is introduced in the regression model as an offset variable. By including \ln [children ever born] as offset in the equation, it is differentiated from other coefficients in the regression model by being carried through as a constant and forced to have a coefficient of one [3]. Thus, the GLM with an offset is given by

$$\log \mu^T \beta$$

2.3.2. Negative Binomial Regression Model

This model is used when count data are overdispersed (i.e when the variance exceeds the mean). The NB regression model is

$$P(y_i) = \begin{cases} \omega_i + (1 - \omega_i)e^{-\mu_i}, & y_i = 0 \\ (1 - \omega_i) \frac{e^{-\mu_i} \mu_i^{y_i}}{y_i!}, & y_i = 1, 2, \dots, 0 \leq \omega_i \leq 1 \end{cases}$$

where, $Y_i \sim \text{ZIP}(\mu_i, \omega_i)$.

2.3.4. Zero-inflated Negative Binomial Regression model

Zero-Inflated Negative Binomial (ZINB) regression is one of the methods used in troubleshooting overdispersion due to excessive zero values in the response variable (excess zeros). The zero inflated negative binomial regression model was

given by

$$P(y_i|\omega, \alpha, \mu) = \begin{cases} \omega_i + (1 - \omega_i)(1 + \alpha\mu_i)^{-\frac{1}{\alpha}}, & y_i = 0 \\ (1 - \omega_i) \frac{\Gamma(y_i + 1/\alpha)}{y_i! \Gamma(1/\alpha)} (1 + \alpha\mu_i)^{-\frac{1}{\alpha}} \left(1 + \frac{1}{\alpha\mu_i}\right)^{-y_i}, & y_i > 0 \end{cases}$$

where, μ_i is the mean of the underlying negative binomial distribution, $\alpha > 0$ is the over dispersion parameter and is assumed not to depend on covariates and $0 \leq \omega_i \leq 1$. Also the parameters μ_i and ω_i depend on vectors of covariates x_i and z_i , respectively. Newton-Raphson iteration procedure can be used for estimating the parameter of ZINB regression models.

2.4. Goodness of Fit Tests

2.4.1. Likelihood Ratio Test

$$LRT_{\alpha} = -2 (LL_1 - LL_2)$$

This statistic has a Chi-squared distribution with 1 degrees of freedom and LL is log-likelihood. If the statistic is greater than the critical value then, the model 2 is better than the model 1.

2.4.2. Vuong Test

The Vuong test is a non-nested test that is based on a comparison of the predicted probabilities of two models that do not nest [5]. The test statistic is

$$V = \frac{\frac{\sum_{i=1}^n m_i}{n}}{\sqrt{\frac{\sum_{i=1}^n (m_i - \bar{m})^2}{n}}}$$

Where, \bar{m} is mean of m_i and n sample size.

The hypotheses of the Vuong test are:

$H_0: E[m_i] = 0$

$H_1: E[m_i] \neq 0$

The null hypothesis of the test is that the two models are equivalent. If $V > Z_{\alpha/2}$, the first model is preferred., if $V < -Z_{\alpha/2}$, the second model is preferred. And if $|V| < Z_{\alpha/2}$, none of the models are preferred.

2.4.3. AIC and BIC

AIC and BIC are goodness of criteria used for model selection.

$AIC = -2 \log \text{likelihood} + 2k$

$BIC = -2 \log \text{likelihood} + k \ln(n)$

where, k = number of parameters and n = number of observations.

3. Results

3.1. Descriptive Statistics

The distribution of socioeconomic, demographic and environmental background characteristics of mothers which affect under-five child mortality is presented in Table 4. Information on the number of deaths of under-five children obtained from a total of 1,807 women in the urban parts of Ethiopia was studied. From these, 328 women experienced

513 under-five deaths. Conversely, 81.8% of the women in urban areas never experienced under-5 death of their children. Nevertheless, 12%, 3.6%, 1.6%, 0.6%, 0.2%, 0.1% and 0.1% of them lost 1, 2, 3, 4, 5, 6 and 7 of their under-five deaths, respectively.

Descriptive statistics for the dependent variable used in the present study are presented in Table 5. The 1,807 observation values obtained for each variable were used in the study. Among the children of the 1,807 women considered in the study, 513 children died before the age of five. While the smallest value for the number of under-five deaths was 0, the highest value was 7. Out of the 1,807 observed values used in the study, 1,479 (81.8%) were zero.

As shown in Figure 1, the distribution of the number of under-five deaths has a rapidly decreasing tail and is highly skewed to right with excess zeros.

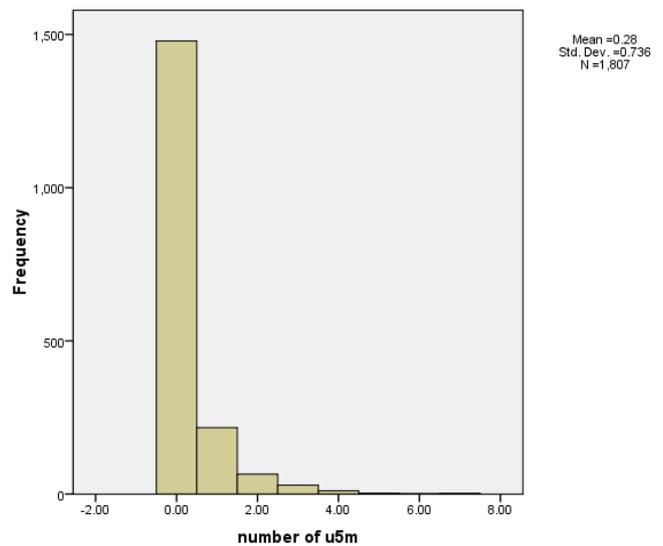


Figure 1. Histogram of the number of under-five deaths.

For urban area, both the Deviance and Pearson statistics divided by the degree of freedom is approximately one in Table 6.

The formal test for significance of over-dispersion, the likelihood ratio test of α , $LRT_{\alpha} = -2 \times (LL_{\text{Poisson}} - LL_{\text{NB}})$, is computed. The likelihood ratio becomes 33.27, which corresponds to a p-value < 0.05 , giving evidence of over-dispersion. Evidence of over-dispersion indicates inadequate fit of the Poisson model. In addition, we can identify more appropriate model by using AIC, BIC and log-likelihood.

Table 7 showed that NB has maximum log-likelihood and minimum BIC and AIC indicating that the negative binomial model fits the data well. Alternatively, we can identify the non-nested models by using vuong test. The value of Vuong statistic, $V = 5.57$ is greater than 1.96 implying that the ZIP

regression model is better than the Poisson regression model. In addition, $V = 4.54$ is greater than 1.96 implying that the ZINB model is better than the NB regression model.

As shown in the Table 9, ZIP regression model has minimum AIC and BIC and maximum log-likelihood. Moreover, the fact that the likelihood ratio of α statistic, $LRT_{\alpha} = -2(LL_{ZIP} - LL_{ZINB}) = 1.41$, is less than $\chi^2(01)$, implies that the ZIP is better than the ZINB regression model since the dispersion statistic ($\alpha = 0.13$) is close to 0.

3.2. Interpretation of Zero Inflated Poisson Regression for Covariates of Non-zero Groups in Urban Parts of Ethiopia

Mother's education level was an important factor for predicting the number of under-five mortality. The expected number of under-five deaths decreased by a factor of 0.50 for mothers with primary education compared to those with no education controlling other variables in the model. Also the expected number of under-five mortality for mothers with secondary and higher education was decreased by a factor of 0.19 and 0.32 as compared to those with no education, respectively, controlling other variables in the model.

As shown in Table 10, toilet facility had a significant effect on the number of under-five deaths. The expected number of under-five deaths increased by a factor 1.58 for a woman with no access to toilet facility as compared to a woman with access to toilet facility holding all other variables in the model constant.

Table 10 revealed that mother's age at the first birth has a significant effect on the number of under-five deaths. The expected number of under-five deaths for mothers in the age group 15-19 had decreased by a factor of 0.64 as compared to the expected number of under-five deaths for mothers in the age group less than 15 controlling for other variables in the model. In addition, the expected number of under-five mortality for mothers in the age group 20 and above was 50% less than that for mothers under 15 years of age controlling for other variables in the model.

Table 10 showed that mothers work status had a significant effect on the number of under-five deaths. The expected number of under-five deaths increased by a factor of 1.59 for working mothers as compared to that for non-working mothers while holding all other variables in the model constant.

3.3. Interpretation of ZIP Regression for Covariate of Zero Counts in Urban Parts of Ethiopia

Table 10 also shows that region has a significant effect on the odds of being in the always zero group. The odds of being in the zero group among children born to mothers in Harari and Addis Ababa increased by a factor of 5.86 and 3.94 to the odds among children born in Tigray, respectively, holding all other variables in the model constant.

As shown in Table 10, mother's marital status has a significant effect on the probability of being an excess zero. The odds of being in the zero groups are increased by a factor

of 2.04 for unmarried mothers as compared to married mothers controlling for other variables in the model.

4. Discussion

This study was carried out to identify the risk factors of under-five mortality in urban areas based on EDHS 2011 data. This study has also identified the risk factors of under-five mortality in urban Ethiopia based on EDHS 2011 data. The total number of urban women covered in the present study was 1,807 of which 18.2% of them experienced under-five deaths due to different factors.

Children from urban areas, whose mothers are in a relatively older age group, were better in their survival status as compared to children whose mothers are in the younger age group. This study revealed that children born to very young (age less than 15 years) mothers are more likely to die. This finding is consistent with the findings of [6-8].

Level of education of Mothers in urban areas showed a significant effect on infant and child mortality. Under-five mortality decreased with increased level of mother's education. This result is consistent with the findings of [6, 8-9].

The under-five mortality risk was lower for women with access to toilet facility than that for women without toilet facility. This finding is consistent with [6, 10]. In addition, children born from working mothers have higher risk of mortality than non-working mothers.

The results of ZIP indicated that region and marital status have a significant factors on the odds of being in the always zero groups. The infant and child mortality widely varied between regions in Ethiopia. The expected number of under-five deaths for women from Oromiya, Benshangul-Gumuz, SNNP and Gambela were higher than the expected number of under-five deaths for women in Tigray. But, the expected number of under-five mortality in Addis Ababa was lower than that of Tigray. This finding is confirmed by the previous researches [11-13].

5. Conclusions

Among the four models considered for analyzing the data from women in urban parts of Ethiopia, the ZIP regression model was found to be the most appropriate model for the data from women in urban areas. Mother's level of education, age of mothers at the first birth, toilet facility and work/employment status of mothers were found to be statistically significant with the number of under-five deaths per mother in urban parts of Ethiopia.

6. Recommendations

Based on this findings we recommend that there is a need for comprehensive prevention strategies that will help to further reduce child mortality, the government/ministry of health should give greater attention to improve immunization services and concentrate on health education campaigns for mothers and for the community and Early marriages should

be discouraged and awareness about the danger of giving birth at early ages should be created through education.

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Author’s Contributions

Conceptualized, designed, analyzed, interpreted the results and wrote the manuscript are done by myself. Mekonnen Tadesse is assisted designing the research and revising the manuscript.

Conflict of Interest Statement

The authors declare no conflict interests.

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Abbreviations

- CSA: Central Statistical Agency
- EDHS: Ethiopia Demographic and Health Survey
- U5CM: Under-five child Mortality
- UNICEF: United Nations Children Fund
- BIC: Bayesian Information Criterion
- AIC: Akaike Information Criterion
- PRM: Poisson Regression Model
- NBRM: Negative Binomial Regression Model
- ZIP: Zero Inflated Poisson
- ZINB: Zero Inflated Negative Binomial
- NB: Negative Binomial
- LRT: Likelihood Ratio Test

Appendix

Table 1. Coding and description of demographic factors.

No.	variable	levels	Descriptions of variables
1	MAGEB	0=<15 1=15-19 2=>=20	Mother’s age at the firth birth
2	CBF	0=No 1=Yes	Mother’s Currently Breastfeeding
3	MS	0=Currently married 1=Currently not married	Mother’s Marital status

Table 2. Coding and description of socio-economic factors.

No.	variable	levels	Descriptions of variables
4	MEDU	0=No education 1=Primary 2=Secondary 3=Higher	Mother’s level of education
5	CMW	0=No 1=Yes	Mother Currently working
6	REG	0=Tigray 1=Affar 2=Amhara 3=Oromiya 4=Somali 5=Benishangul-Gumuz 6=SNNP 7=Gambela 8=Harari 9=Addis Ababa 10=Dire Dawa	Region
7	WI	0=Poor 1=Medium 2=Rich	Household’s wealth index
8	PRES	0=Urban 1=Rural	Place of residence

Table 3. Coding and description environmental factors.

No.	variable	levels	Descriptions of variables
9	SDW	0=protected 1=unprotected	Source of drinking water
10	TF	0=has toilet facility 1=no toilet facility	Toilet facility

Table 4. Distribution of number of under-5 deaths in urban parts of Ethiopia.

Number of deaths Per mother	Frequency	percent
0	1479	81.8
1	217	12.0
2	65	3.6
3	29	1.6
4	11	0.6
5	3	0.2
6	1	0.1
7	2	0.1
Total	1807	100.0

Table 5. Summary data for the number of under-five deaths.

	Minimum	Maximum	Mean	Variance	Skewness	kurtosis
Number of under-5 deaths	0.00	7.00	0.2839	0.541	3.658	17.723

Table 6. Tests of over-dispersion.

Statistics	value	Degree of freedom	$\frac{\text{value}}{\text{degree of freedom}}$
Deviance	1225.381	1789	0.70
Pearson Chi-Square	1870.536	1789	1.05

Table 7. Model comparisons.

Fit statistics	Poisson	NB
Log-likelihood	-986.83627	-970.20254
AIC	2009.673	1978.405
BIC	2108.662	2082.894

Table 8. Model comparisons by Vuong test for non-nested models.

Model	Vuong statistics(V)	Preferred model
ZIP VS Poisson	5.57	ZIP
ZINB VS NB	4.54	ZINB

Table 9. Fit statistic for count regression models.

Criteria	Poisson	NB	ZIP	ZINB
LL	-986.83627	-970.20254	-961.6857	-962.3918
AIC	2009.673	1978.405	1964.784	1965.371
BIC	2108.662	2082.894	2074.772	2080.859
LRT _α (p-value)	33.27 (0.000)		1.41 (0.1173)	

Table 10. Estimated coefficients of ZIP regression model.

variables	Coef.	Std. Err.	z	P> z	[95% CI]
Mother level of education, no education (ref.)					
primary	-0.6851459	0.118065	-5.8	0.000	-.916549 - .4537427
secondary	-1.644393	0.284829	-5.77	0.000	-2.202648 -1.086139
higher	-1.124482	0.3034474	-3.71	0.000	-1.719228 - .529736
Toilet facility, has toilet facility (ref.)					
No toilet facility	0.4553794	0.1026778	4.44	0.000	.2541347 .6566242
Mother age at the first birth, <15 (ref.)					
15-19	-0.4387141	0.1579696	-2.78	0.005	-.7483289 - .1290994
20 and above	-0.6916586	0.1660779	-4.16	0.000	-1.017165 - .3661518
Current mother working, no (ref.)					
yes	0.4616567	0.0971435	4.75	0.000	.271259 .6520544
_cons	-0.6435852	0.1602475	-4.02	0.000	-.9576645 - .3295059
log(children ever born) inflate	1.000				
REG, Tigray (ref.)					
Affar	-1.249948	1.209543	-1.03	0.301	-3.620608 1.120713
Amhara	0.157807	0.68059	0.23	0.817	-1.176125 1.491739
Oromiya	0.0361875	0.6850303	0.05	0.958	-1.306447 1.378822
Somali	-1.367464	0.8548237	-1.6	0.11	-3.042888 .3079594
Benshangul- Gumuz	-0.1943995	0.7757449	-0.25	0.802	-1.714832 1.326032

variables	Coef.	Std. Err.	z	P> z	[95% CI]
SNNP	0.9807198	0.7509466	1.31	0.192	-.4911086 2.452548
Gambela	0.3106566	0.7214726	0.43	0.667	-1.103404 1.724717
Harari	1.768236	0.6238823	2.83	0.005	.5454497 2.991023
Addis Ababa	1.370265	0.585421	2.34	0.019	.2228606 2.517669
Dire Dawa	0.7982654	0.5829998	1.37	0.171	-.3443933 1.940924
Marital status, married (ref.)					
Unmarried	0.7145814	0.3060955	2.33	0.02	.1146451 1.314518
cons	-0.7635159	0.5529071	-1.38	0.167	-1.847194 .3201622

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