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RESEARCH ARTICLE

ENVIRONMENTAL DETERMINANTS OF CHILD MORTALITY IN ETHIOPIA: AN APPLICATION OF SURVIVAL ANALYSIS

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ABSTRACT

This paper focuses on the environmental determinants of child mortality in Ethiopia. The data for this study were obtained from the demographic and health survey conducted in 2014. It specifically examines how child mortality is related to the household's environmental characteristics, such as mother's education, source of drinking water, type of toilet used, type of cooking fuels, antenatal visit and place of delivery. A survival analysis was used to analyze the determinants of child mortality. As expected the Kaplan-Meier estimation show that most of the deaths occurred at first birth day of life. As the result of this we employed Cox proportional hazard and weibull regression models to select factors affecting child mortality in Ethiopia. According to the Cox proportional hazard and weibull regression models, mothers' education, source of drinking water, type of toilet used, antenatal visit, place of delivery and type of cooking fuel were found to have significant impact on child mortality in Ethiopia. Child's mother who had primary, secondary and above educational level were lower risk of mortality than mothers' who had no education level and children whose parents use non-improved source of drinking water have less survival chance than those who use improved source of drinking water. With regard to source of cooking fuel, children born in households using high polluting fuels (fire woods and charcoal) as their main source of cooking fuel have higher mortality rates as compared to those using low polluting fuels (electricity). Children born in households with either flush toilets or pit latrines have lower mortality rate than those born in households without any toilet facility. Policies aimed at achieving the goal of reduced child mortality should be directed on improving the household's environmental status if this goal is to be realized.

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INTRODUCTION

Child mortality, commonly on the agenda of public health and international development agencies, has received renewed attention as a part of the United Nation's. Approximately 6.3 million infants and children under five years of age die each year, with large variations in under-five mortality rates, across regions and countries (WHO, 2010, UNICEF, 2013). Globally, the under-five mortality rates have declined from 85 per 1000 to 51 per 1000 (UNICEF, 2012). However, it is estimated that more than 7 million children will die before attaining the age of five. Of these, India, Pakistan, Ethiopia, Nigeria and Democratic Republic of Congo will suffer half of all under-five children deaths (UNICEF, 2012). India alone shares the burden of 24% of world's under-five mortality followed by Nigeria which shares 11% of this burden (UNICEF, 2012). It is obvious that health policies in these five countries need to be reviewed and new imputes provided to bring down the high under-five mortality rate.

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Environmental conditions are a major direct and indirect determinant of human health. In developing societies, modern forms of exposure to urban, industrial and agrochemical pollution add to the health burden caused by traditional household and community-based risks. The vicious cycle, intrinsically linking poverty, environmental degradation and ill health needs to be broken. In most developing countries, especially in Sub- Saharan Africa (SSA), the basic child mortality causes of more than 80% of the diseases are inadequate and unsafe water supply, and improper disposal of waste (WHO 2010). Child mortality varies among world regions but the highest prevalence is concentrated in Sub-Saharan Africa where mortality of children under five decreased from 177 in 1990 to 98 deaths per 1,000 live births in 2012 (UNICEF, 2013). Despite the overall decline in the prevalence of child mortality, it remains still at unacceptably high levels. About half of all deaths of children under five has been concentrated in Sub-Saharan Africa in 2012 (UNICEF, 2013). Hence, the need to reduce child mortality is one of the major challenges in improving child health, in particular in Sub-Saharan Africa. Similarly empirical research used aggregated macro data to study the determinants of child

health outcomes. For example, Hmwe H. *et al*. (2013) show, based on a longitudinal study for 193 countries using annual data between 2000 and 2009 from the World Development Indicators, that GDP per capita, access to safe drinking water, improved sanitation, and public health expenditure per capita increases the probability of child survival. The health effects of such environmental determinants were highlighted in the World Health Organization's 2010 World Health Report (WHO 2010), which showed that unsafe water, poor sanitation, and hygiene are the cause of 4%–8% of the overall burden of diseases in developing countries and nine-tenths of diarrheal diseases, which is a major contributor to infant mortality. According to World Bank (2013), environmental health risks fall into two broad categories. The first are the traditional hazards related to poverty and lack of development, such as lack of safe water, inadequate sanitation and waste disposal, indoor air pollution, and vector-borne diseases. The second category is the modern hazards such as rural air pollution and exposure to agro industrial chemicals and wastes that are caused by development that lacks environmental safeguards. Unsafe water and sanitation, indoor air pollution from household solid fuel use, and ambient urban particulate matter (PM) pollution are responsible for an estimated 3.4%, 2.7%, and 0.6% of the global burden of disease, respectively, with 90%, 71%, and 7% of the disease burden from these risk factors borne by infants and young children in low- and middle-income countries.

As the world enters into the 21st century, debate on childhood mortality remains a big issue for developing countries. Their commitment is reflected in their desire to reduce the level of child mortality by two- thirds of their 1990 levels by the year 2015, as expressed in the Millennium Development Goals. To achieve this goal, it is imperative to attempt and determine what factors contribute to the high levels of child mortality in developing countries and in particular, Ethiopia. Worldwide, safe and adequate drinking water is still not accessible to 1.1 billion people, and 2.4 billion people lack adequate sanitation. The recent figures for Ethiopia (2010) indicate a water supply coverage of 38% (98% in urban areas and 26% in rural areas), and a sanitation coverage of 15% (58% in urban areas and 8% in rural areas). Unchecked urban growth has its price in terms of environmental health: disposal of municipal and hazardous waste, particularly health care waste, remains a problem in many regions. Up to 60% of the global burden of Acute Respiratory Infection (ARI) is associated with indoor air pollution and other environmental factors. Occupational diseases and injuries, grossly underreported are responsible for more than 1 million deaths annually all over the world; health care workers, miners and manufacturing workers are at highest risk.

Ethiopia has one of the lowest rates of coverage for improved water and sanitation in the world. Just over 54 per cent of households have access to an improved source of drinking water, with a higher proportion among urban households (75%) and among rural households (49%). According to Joint Monitoring Program (JMP) 2012 update, the proportion of the population having access to improve and unimproved sanitation facilities stands at 54 % (21% improved and 33 % unimproved).

- **Nearly 39 million Ethiopians –** most of them in rural areas don't have access to safe water.
- Nearly 48 million lack access to basic sanitation.

Environmental conditions, in particular, a safe source of drinking water, appear to be important determinants of infant mortality risks in both urban and rural locations. In the latter, the very few households with an electricity supply have a greatly reduced probability of infant death. In urban areas, the mortality risk is substantially higher among households living in premises with no finished floor. It seems likely that this characteristic identifies slum dwellings and the poor public health conditions found there. In rural areas, the majority of dwellings have no finished floor, and this is not significantly correlated with mortality risk. Surprisingly, having a toilet is not significantly correlated with mortality risk in either urban or rural areas. Children in households with fewer assets face a greater risk of death in urban but not in rural areas. This is consistent with a greater socio economic gradient in child health in urban areas that has been found in other studies (Kyei, 2012).

Data and Methodology: The source of the data used in this study was the 2014 Ethiopia Demographic and Health survey (EDHS, 2014) conducted in Ethiopia as part of the worldwide demographic and health survey project.

Study Variables

Dependent Variable: The time is dependent variable and is defined as the time that a child who has survived to the beginning of the respective interval (12 months-59 months) will fail (die) in that interval.

Independent Variables: The main focus of this study was on the environmental variables only. The explanatory variables are sex of child, place of residence, women education level, antenatal visit, households' access to water, household access to toilet, cooking fuel type and Place of delivery.

MATERIALS AND METHODS

Survival Analysis involves the modeling and analysis of data that have a principal end point, the time until an event occurs (time-to-event data). Generally, survival analysis is a collection of statistical procedures for data analysis for which the outcome variable of interest is time until an event occurs.

Methods of Statistical Data Analysis: In this study, nonparametric, semi-parametric, and parametric survival analysis approaches were used to analyze the survival time of child.

RESULTS

Among the total number of mothers' (2120), 1759 (83%) were not pre-birth follow up during pregnancy period and 361(17%) mothers' dose pre-birth follow up during pregnancy period. In addition, 372 mothers' delivered in health center, 1741 mothers' delivered at home and the rest 7 delivered on other places like road. Finally, 144 (79.6%) children death were due to non-improved source of drinking water and 37(20.4%) of death of children were in the case of improved water source.
The median survival time of a child was 36 months with a standard error of 0.204 for the follow-up period of time. In addition, the plot of overall Kaplan-Meier estimate indicate that for child mortality monotonically decreases as follow up time increases.

Table 1. Result of log-rank test of equality of survival distribution for the different categorical covariates

Covariates	Chi-Square	Df	p-value
Sex of child	2.785	1	0.095
Place of Residence	52.99	1	0.000
Mothers Educational Status	34.748	2	0.001
Toilet Type Used	36.253	2	0.001
Type of Cooking Fuel	26.697	3	0.004
Antenatal visit during pregnancy	59.058	1	0.001
Place of Delivery	8.670	2	0.067
Source of drinking Water	41.378	1	0.000

Table 2. The Preliminary Final Model with parameter estimates and hazard ratios of the covariates

	B	SE	Wald	Df	Sig.	HR	95.0% CI for Exp(B)	
							Lower	Upper
Place of Residence Urban(1) Rural(2) (Ref)	-.648	.272	5.674	1	.017	.523	.307	.891
Mothers' Education Status			12.293	2	.002			
No Education(1) Primary(2) Secondary & above 3(Ref)	1.469	.748	3.857	1	.050	4.343	1.003	18.811
	-.634	.270	5.504	1	.019	.531	.312	.901
Toilet Type Used			8.204	2	.017			
Improved(1) Shared facility(2) Non-improved 3(Ref)	-1.301	.461	7.968	1	.005	.272	.110	.672
	.014	.798	.000	1	.986	1.014	.212	4.842
Type of Cooking Fuel			8.471	3	.003			
Fire wood (1)	1.252	.458	7.461	1	.006	3.497	1.424	8.588
Charcoal (2)	.989	.514	3.703	1	.045	2.688	1.982	8.359
Kerosene (3)	.844	.656	1.655	1	.198	2.326	.643	8.421
Electricity 4(Ref)								
Antenatal Visit No (0) Yes(1) (Ref)	1.085	.281	14.868	1	.000	2.959	1.705	5.135
source of drinking water improved (1) p-value (0.000) should be "0.001	-1.050	.193	29.590	1	.000	.350	.240	.511

Table 3. The Likelihood Ratio, Score and Wald tests for overall measures of goodness of fit of the preliminary final model in Table 2

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	121.1679	6	<.0001
Score	108.1439	6	<.0001
Wald	102.8381	6	<.0001

Table 4. Result of test of proportionality assumption for each covariate in the final model

Linear Hypotheses Testing Results			
Label	Wald Chi-Square	DF	Pr > ChiSq
Test proportionality	8.1448	6	0.4195

Table 5. Statistical results for model comparison

Model	Observation	ll (null)	ll (model)	Df	AIC value	BIC value
Exponential	2120	-600.9143	-542.6691	11	1107.338	1169.589
Weibull	2120	-395.6862	-324.8979	12	673.7959	741.7059

As noted above the p-values of the log-rank test showed that the survival experience of children in the various categories antenatal visit, mothers educational status, toilet type used , type of cooking fuel, source of drinking water and place of residence were differ significantly (i.e. all of these covariates have P-value less than 0.05). Mother's education is the most important determinant of child mortality among the mother's characteristics that are considered in this study. Children whose mothers' have no education are 50.81% likely to die as infants compared with children whose mothers have secondary and above education (HR = .5081; 95% CI=(.2788-.9260)). The risk of death of children whose mothers' have primary education level was 44.58% compared to the reference group secondary and above education level (HR=.4457; 95% CI=(0.2714-0.7320)) keeping effects of other covariates constant. After adjusting other covariates, the estimated coefficients of improved and shared toilet types are -1.301 and 0.014 respectively.

The hazard ratio or relative risk of the covariate toilet type used improved is 1.014 and it is as little as 0.272. It means that the hazard rate of child reduce by 72.8 % in household with sanitary latrine as compared with the household without sanitary latrine (shared facility). In favor of this finding, Klaauw and Wang (2004)**,** suggest that good public sanitation systems may constitute a more important preventive aspect of child survival. In the latter study of Kabir & Amin (2013)**,** in Bangladesh also highlights that the households with sanitary latrines have low risks of child mortality.

The risk of dying for a child born in a family without access to improved (pipe) source of drinking water is higher by 35% relative to those born in a family with access to improved drinking water. The 95% confidence interval (0.240, 0.511) implies that the risk of death of children whose source of water is not improved water is 0.240 as low and 0.511 as high as those in the reference group.

Table 6. Parameter estimates of the final multivariate weibull regression model

Covariate	Hazard ratio	Std.error	Z	P>|z|	95% CI	
					Lower	Upper
PResidence(1)	.5877572	.168221	1.86	0.043	.3354108	.929957
PResidence(Ref)						
Mothers' Educational status						
No education(1)	.5081227	.1555982	-2.21	0.027	.2788125	.9260298
Primary(2)	.4457565	.1128284	-3.19	0.001	.2714216	.7320673
Secondary&above(Ref)						
Toilet type used						
Improved(1)	.3312088	.1464452	-2.50	0.012	.1392322	.7878869
Shared facility(2)	1.142547	.8782884	0.17	0.862	.2532478	5.154685
Non-improved(Ref)						
Type of Cooking Fuel						
Fire wood (1)	3.323802	1.29274	3.09	0.002	1.550865	7.123548
Charcoal (2)	2.752342	1.269107	2.20	0.028	1.11484	6.79504
Kerosene (3)	2.149882	1.382608	1.19	0.328	.6095359	7.582803
Electricity(Ref)						
Antenatal Visit No (0)	3.174416	.9498236	3.86	0.000	1.765932	5.706287
Yes(1) (Ref)						
source of drinking water improved						
(1) , Cons and /ln_p p-value (0.000)	.2843618	.0539307	-6.63	0.000	.1960814	.4123881
should be "0.001						
_cons	2.00e-09	2.44e-09	-16.43	0.000	1.84e-10	2.19e-08
/ln_p	1.713488	.0558461	30.68	0.000	1.604032	1.822944
P	.54828	.3098497			4.973042	6.190057
1/p	1.8238	.0100655			.1615494	.2010842

Remark: The reference category is marked by parenthesis (Ref).

This result is in accordance with Unger (2013). But other researchers depicts that source of drinking water has no significant effect on child mortality. (Abdul Hamid Chowdhury 1, Mohammad Emdad Hossian 2, Md. Musa Khan 3,Mohammad Nazmul Hoq 4, Asian Journal of Social science and humanities, Bangladish Vol.2 No.2 May 2013). The estimated hazard ratio for children whose mother's attended antenatal visits during pregnancy when compared to those mothers who did not attend antenatal visit was 2.959 (95% CI:1.705-5.135) keeping effects of other covariates constant. That is, children whose mothers attended antenatal visits during pregnancy had 95.9% lower risk of child mortality than those who did not attend antenatal visit. In other words the risk of death for children, mother's who did not attend antenatal visit was 2.959 times relative to whose mother's attended antenatal visits during pregnancy. With regard to households' source of cooking fuel, the risk of dying for children with fire hood, charcoal and kerosene were 3.497, 2.688, and 2.326, respectively. These figures shows that the risk of death children whose house hold cooking type of fuel, fire hood is 3.497 times relative to households type of cooking fuels is electricity. In other words, after adjusting other covariates, the hazard of death of children with households use fire hood cooking is 3.497 times higher than households use electricity (adjusted HR=3.479, 95% Cl:1.424-8.588). The hazard death of children for household use charcoal cooking is 2.688 times higher than households use electricity (adjusted HR=2.688, 95% Cl:1.982-7.36). The hazard death children for households use kerosene cooking fuel is 2.326 times higher than households use electricity (adjusted HR=2.326,95% Cl:1.643-8.421). All these findings are consistent with Hala (2002), Klaauw and Wang (2004) and Jacoby and Wang (2003). As we can see from Table 3: the p-values associated with the likelihood ratio, Score and Wald test statistics are all less than 1% indicating goodness of the fitted model at 5% level of significance. According to the results in Table 5 above, the Weibull regression model with the smallest value of AIC and BIC seems to be the best fit of the two models. Nevertheless, the results of cox-snell were consistent with the results based on Akaikie's information criterion. Thus, the Weibull regression model was preferable to discuss the effect of covariates on the survival of Child mortality in Ethiopia.

DISCUSSION

The main aim of this study was to identify factors of child mortality in Ethiopia using the nationally representative of 2014, EDHS data. Both univariate and multivariate statistical analyses were employed to examine factors affecting child mortality. The analyses revealed that environmental variables were statistically significant effect on child mortality in Ethiopia. The variables influencing child mortality are mothers' educational status, source of drinking water, place of residence, household type of toilet used, type of cooking fuel and antenatal visits. But covariates like sex of child and place of delivery were not statistically significant on child mortality in Ethiopia. The findings of this study showed that children whose mothers attended antenatal visits during pregnancy had lower risk of child mortality than those who did not attend antenatal visits. A study in the Gaza Strip, occupied Palestinian territory, by Antai D. and Moradi T. (2010) found that newborn babies born to mothers who attended fewer than four antenatal sessions during pregnancy had a risk of dying that was almost twice that of those born to mothers who attended antenatal session four or more times. A study in Indonesia also revealed that the risk of children death was higher among women who did not attend antenatal care visits during pregnancy (Kamal S.M.M. (2012). A study in Ethiopia by Desta, M. (2011) showed that child mortality was associated with antenatal care follow-up: there was better survival with at least one antenatal care follow-up. Thus, antenatal care follow-up is a prominent predictor of survival time of children. The result of this study also showed that children whose parents used unprotected drinking water have less survival chance than those who use piped drinking water or improved source of drinking water. A study in China showed that access to safe water or sanitation reduces child mortality risks by about 34% in rural areas, which means access to safe water/sanitation, and immunization

reduce diarrhea incidence in rural areas (Jacoby and Wang (2003)). In Kenya, Mutunga (2004) found that child survival was found better for those who had access to safe drinking water and sanitation facilities. A study in Egypt by Hala (2002) showed that access to municipal water decreases sanitary risks. Access to municipal water and improved sanitation facilities had significant positive impact on children mortality (Unger (2013)). Therefore, higher mortality rates are experienced in households that have access to unprotected source of drinking water drinking water. The probability of dying child for females compared to males found in this study was the same. It was not significant impact on environmental determinant of child mortality. But other study showed that there is a significant impact on child mortality. Likewise, more boys die before their first birth day than girls in Kenya (Hill et al., 2001).

Conclusion

The study employed survival statistical analysis to determine risk factors associated with child mortality in Ethiopia. Both Cox Proportional hazard model and Weibull regression model analysis techniques have been applied to identify the important predictors of child survival. The results from the Kaplan-Meier estimate showed that most of the deaths occurred during the first birth days of life. Results based on Proportional Hazards model and weibull model revealed that environmental factors had statistically significant effect on child mortality. Specifically, the study demonstrated that various factors such as mothers' education, household source of drinking water, antenatal visit, place of delivery, type of cooking fuel and type of toilet used had statistically significant impacts on the survival experience of children. But covariates like sex of child and place of residence were insignificant on survival of child.
The two parametric regression models: Exponential and Weibull regression models, for survival probability of children were compared.

The Weibull regression model was found to better fit to the data. The findings further suggested the following: Mothers' educational and households source of drinking water had a significant effect on survival of child, that is, child mothers' who had primary, secondary and above educational level were lower risk of mortality than mothers' who had no education level. Children whose parents use non-improved has less survival chance than those who use improved source of drinking water. With regard to source of cooking fuel, children born in households using high polluting fuels (fire woods and charcoal) as their main source of cooking fuel have higher mortality rates as compared to those using low polluting fuels (electricity). Children born in household with either flush toilets or pit latrines have lower mortality rate than those born in households without any toilet facility.

Ethical consideration: This work has been approved by the ethical review committee of University of Gondar, Collage of Natural, and Computational Sciences.

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