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Determinants of under-five Mortality in Nigeria: An application of Cox proportional hazard and Cox frailty models.

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Abstract: *Many researchers in Nigeria have made efforts during the past decades to determine the significant demographic characteristics associated with child mortality using multiple linear regression, logistics model, Cox proportional hazard model and so on but little has been done using Frailty Models which incorporates the term frailty which measures the unobserved heterogeneity among under-five children at individual level.Using the 2008 NDHS, this study is aimed at investigating frailty among individuals, determining those demographic characteristics responsible for under-five child mortality and hazard rates in Nigeria. The Traditional Cox Proportional hazard model and Cox Frailty model were employed. The results indicate the presence of frailty by p-value 0.000. Differential of mother's age and education were significant determinants of under-five mortality with a significance level of 0.01. Mothers who are of age group less than 20 years have the highest hazard ratio of 121%. This study therefore recommends that mothers should be educated on child care and younger women of age group 20-24 should give birth at such ages since they have lower risk of child death.*
Keywords: *under-five child Mortality, Cox Proportional hazard model, Cox Frailty model.*

I. Introduction

Child mortality is one of the most important sensitive indicators derived from mortality rates which provide a good picture and assessment of overall population health. The term child mortality is a composite index reflecting environmental, social, economic, health care services and delivery situation on one hand and maternal as well as family, community norms and practices on the other. Health and life actuaries have always had special interest in the development and construction of mortality rates. As actuarial mortality reflect a country's socio-economic level of development, quality of life and a host of other programs.

Reduction of mortality rate among under-five children by two-thirds between 1990 and 2015 is the fourth United Nations' Millennium Development Goals. The progress of any country depends on how healthy the children are. Such children should have access to basic health care, nutritious food and a protective environment. When these are not available, the country's mortality rates would increase and economic potentials diminish. Globally, in 2011, 6.9 million under five children died, down from 7.6 million in 2010, 8.1 million in 2009 and 12.4 million in 1990.There has been a reduction from 12.4 million in 1990 to 6.9 in 2011 (UNICEF), majorly due to interventions targeted at communicable diseases such as malaria, measles, diarrhea, respiratory infections, other immunizable childhood infections and malnutrition. However, these health gains were short lived especially in Africa because disease oriented vertical program alone were not effective (Mutunga, 2007). Environmental, maternal and socio-economic factors were acknowledged as additional important determinants of child survival (Espo, 2002).UNICEF (2010) in the state of the world's children report noted that 8.1 million children across the world who died in 2009 before their fifth birthday lived in developing countries and died from a disease or a combination of diseases that could easily have been prevented or treated. It also noted that, half of these deaths occurred in just five countries namely, India, Nigeria, the democratic republic of Congo, Pakistan and China; with India and Nigeria both accounting for one third of the total number of under-five deaths worldwide. The national representative 2008 NDHS has estimated under five mortality rates at 157 children per 1,000 live births. It means that 1 out of 6 children die before their fifth birthday in Nigeria.

With the year 2015 set for the attainment of these goals, child mortality is on the increase in Nigeria as the latest report on the MDGs shows mortality rate above 100 per 1000 births. In developing countries like Nigeria, efforts (socio-economic development and implementation of child survival intervention) majorly targeted at communicable diseases have been made during the past decade to reduce child mortality. Despite these, child mortality is on the increase in Nigeria. This prevailing high mortality may be due to frailty (heterogeneity) at individual level. It is therefore important to explore the latest Nigeria Demographic and Health Survey data to identify the factors responsible for the persistently high under-5 mortality in Nigeria.

II. Data And Methods

The data used for this work is a secondary data obtained from the 2008 National Demographic Health Survey (NDHS). The survey was designed to capture information from the 6 zones and 36 states plus the Federal Capital Territory, Abuja of Nigeria. The 2008 NDHS sample was selected using a stratified two-stage cluster design consisting of 888 clusters, 286 in the urban and 602 in the rural areas. A representative sample of 36,800 households was selected for the 2008 NDHS survey. In the second stage of the selection, an average of 41 households was selected in every cluster, by equal probability systematic sampling. All women age 15-49 who were either permanent residents of the households in the 2008 NDHS sample or visitors present in the households on the night before the survey were eligible to be interviewed.

The outcome variable of the study was the survival time of a child i.e. the length of time from birth until the date of death measured in months (i.e. one to 60months). The predictors of mortality used in this work include sex, birth size, birth order, breastfeeding, delivery type, delivery place, mother's age, mother's education, father's education, proceeding birth interval, wealth index, residence, religion, toilet type, and water source.

The main concept of this work is aimed at identifying frailty among individuals and estimating the determinant of under-5 mortality rate in Nigeria. Survival models; Cox proportional hazard model and Cox Frailty models were employed to analyzed the data.

2.1 Cox proportional Hazard Model

Cox proportional hazard model is a model which is often used in survival analysis. Cox proportional model is one that could estimate the relationship between the hazard rate and explanatory variables without having to make assumptions about the shape of the baseline hazard function. Hence the Cox model is sometimes referred to as a semi-parametric model.

The model specification is $h(t,x) = h_o(t)\exp(\beta_1 X_1 + \beta_2 X_2 + ... + \beta_P X_P)$

In matrix notation written as

$$h(t,x) = h_o(t)\exp \beta^T X$$

Where $h(t,x)$ is the hazard rate which depend on time until death and covariates

$h_o(t)$ is the baseline hazard that depends on time until death but not covariates

$\exp(\beta^T X)$ is the term that depends on the covariates but not time

$\beta_1, \beta_2, ..., \beta_P$ are the regression coefficients

$X_1, X_2, ..., X_P$ are covariates or explanatory variables

2.2 Cox Frailty Model

2.2 Cox Frailty: Vaupel et al. (1979) introduced the term frailty in order to account for unobserved heterogeneity, random effects. A frailty model is a generalization of a survival regression model. In addition to the observed regressors, a frailty model also accounts for the presence of a latent multiplicative effect on the hazard function. This effect, or frailty, is not directly estimated from the data, but instead is assumed to have unit mean and finite variance, which is estimated. Frailty models can provide a useful alternative to a standard survival model when the standard model fails to adequately account for all the variability in the observed failure times. Therefore, the objective is to introduce an additional parameter to the hazard rate that accounts for the random frailties. Ignoring the existence of frailty will produce incorrect estimation of parameters and their standard errors in survival analysis.

Cox-Frailty model specification: $h(t \mid \alpha) = \alpha h_o(t)\exp \beta^T X$

Where α is some random positive quantity assumed to have mean one (for purposes of model identifiability) and variance θ. α is distributed as gamma with mean one and variance θ,

$$g(\alpha) = \frac{\alpha^{1/\theta - 1}\exp(-\alpha/\theta)}{\Gamma(1/\theta)\theta^{1/\theta}}$$

R software programme was used. R uses the Newton–Raphson method to estimate the parameters.

III. Results & Findings

The Cox and Cox Frailty models were applied to fifteen demographic characteristics listed above. The study was designed to determine frailty among under-five children and those factors that affect the survival of children in Nigeria. The tables1 and 2 below show the significant factors of under-five mortality in Nigeria.

Table 1: Cox Model showing the significant factors of under-five child mortality

Covariates	Coeff	Hazard ratio	Std Error	Chisq	p-value
Mother's Age					
<20	0.1897	1.2089	0.0364	27.23	0.0001
20−24	-	-	-	-	-
25−29	−0.0821	0.9211	0.0207	15.75	0.0001
30−34	−0.1201	0.8869	0.0229	27.45	0.0001
≥35	−0.1300	0.8781	0.0226	33.18	0.0001
Mother's Education					
No Education	−0.1911	0.8261	0.0393	23.68	0.0001
Primary Education	−0.1938	0.8238	0.0400	23.44	0.0001
Secondary Education	−0.1938	0.8800	0.0402	10.13	0.0015
Higher Education	-	-	-	-	-

Level of significance= 0.01

Table 2: Cox-Frailty Model showing the significant factors of under-five child mortality.

Covariates	Coeff	Hazard ratio	Std Error	Chisq	p-value
Mother's Age					
<20	0.1898	1.2090	0.0364	27.24	0.0000
20−24	-	-	-	-	-
25−29	−0.0822	0.9211	0.0207	15.76	0.0000
30−34	−0.1202	0.8867	0.0229	27.46	0.0000
≥35	−0.1301	0.8780	0.0226	33.19	0.0000
Mother's Education					
No Education	−0.1911	0.8260	0.0393	23.44	0.0000
Primary Education	−0.1939	0.8237	0.0400	23.67	0.0000
Secondary Education	−0.1278	0.8800	0.0402	10.13	0.0015
Higher Education	-	-	-	-	-

Variance of random effect=0.000542 p value = 0.0000

Level of significance= 0.01

The fitted Cox proportional hazards regression model showed that differentials of mother's age and education were significantly associated with the death of under-five children. On the introduction of frailty components, the same demographic characteristics as the Cox model also contributed significantly to under-five child mortality. Also there is a slight change in parameter estimate and the standard error. From the Cox-frailty regression, the variability among the children is 0.000542 with p-value 0.000.This implies that frailty is present among individual children. There are differences among these children but minimal and when exposed to these demographic characteristics, their chance of survival is low.

Mother's Age: The reference group was the age group 20-24 years. Among the estimated hazard ratios, the age group less than 20 years has the highest hazard ratio followed by 25-29, 30-34 and lastly greater than or equals 35. Children born to mothers of age group less than 20 years died at a rate of about 121% times higher than children born to mothers of age group 20-24. Children born to mothers of age group 25-29years of age died at a rate of about 92% times higher than children born to mothers of age group 20-24years.Children born to mothers of age group 30-34 years died at a rate of about 89% times higher than children born to mothers of age group 20-24 years. Children born to mothers of age group greater than or equals 35years died at a rate of about 88 % times higher than children born to mothers of age group 20-24 years.

Mother's Education: In this case, higher education was taken as the reference group. The hazard rate is highest for those with secondary level of education followed by no education, and lastly primary level of education. Children born to mothers with no level of education died at a rate of about 83% times higher than children born to mothers of higher level of education. Children born to mothers with primary level of education died at a rate of about 82% times higher than children born to mothers of higher level of education. Children born to mothers with secondary level of education died at a rate of about 88% times higher than children born to mothers of higher level of education.

IV. Conclusion And Recommendation

Significant mortality differentials by maternal age at birth of child were observed. The Cox-Frailty regression result shows that teenage mothers who are less than 20 have the highest risk of death. These could be as a result of younger women who may have immature reproductive systems which are not yet ready to handle the complexities of child birth. Also younger mothers are not yet ready to take on parental responsibilities. Such mothers are less likely to have decision-making authority within the household and more likely to lack financial resources to seek medical attention for their children. Additionally, due to social stigma associated with being young mothers, they may not seek prenatal care and therefore, any complications related to the pregnancy may go undetected until it is too late. Differentials by maternal education are significantly associated with child survival for under-five children. There are several mechanisms through which education affects child survival. Higher child survival among educated mothers has been attributed to higher socioeconomic status resulting from education, its improvement of maternal basic childcare skills, her domestic management of child illness, efforts at preventive care and effective use of modern health services (Das Gupta, 1990; Caldwell, 1979; 1994). Additionally, education gives mothers a greater say in childcare issues. For instance educated mothers are more likely to seek medical attention for their children and to enjoy favourable responses from the medical personnel; survival chances of their children are likely to be higher.

Based on the outcome of this research work and available information, this study urges the policy makers to focus on educating illiterate mothers and increase education for women who are literate about child's care. However, policy aiming at improving maternal education is needed for sustainability. Mothers should be strengthened and empowered through wealth creation programmes and decision making about seeking care for their children as these are essential strategies that will reduce the death of children.

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