# BINOMIAL-MIXTURE MODELS ON UNDER-FIVE MORTALITY IN NIGERIA

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## ABSTRACT

The reduction of under-five mortality (U5M) in Nigeria remains a challenge. Many studies have looked into factors associated with U5M by using single or standard models such as binary logistic regression, cox-proportional hazards, regression and probit models for categorical response variable. To accurately estimate the impact of these factors on U5M, a mixture model of this type of binary response variable, is needed. This study was aimed at addressing this situation. The data from Nigeria Demographic and Health Survey 2018 (NDHS 2018) were analyzed among mothers aged 15 – 49 years. The response variable was "died" or "alive" for each child birth. The Binomial Mixture models (Logit, Probit, Cloglog and Zero Inflated Binomial models) was used. The Akaike Information Criterion (AIC) and Residual Deviance (RED) were the criteria used to select the model. The lowest AIC and RED indicated the best model. The models had the following AIC and RED: (52129; 33103), (52170; 33144), (52114; 33088) and (50854; 29865) for Logit, Probit, Cloglog, and Zero Inflated Binomial Models respectively. The best model was the Zero Inflated Binomial Model because it had the lowest AIC and RED. The risk factors associated with U5M in Nigeria are living in the North- East and North West, Parents Education, Religion, wealth index, Types of toilet and Breast-feeding.Zero Inflated Binomial model was the best model for measuring factors associated with U5M in Nigeria. The risks factors identified in this study should be given serious attention, especially the education of both parents. Also, health education, be facilitated on importance of exclusive breast-feeding.

**Key words:** Mixture model, Zero Inflated Binomial model, AIC, RED, Nigeria

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## Introduction

Under-five mortality has remained an important public health challenge in Nigeria. World mortality report highlighted that despite some noticeable reduction in the trend of U5M, an increasing proportion of deaths occurred in sub-Saharan Africa and Southern Asia. This has called into question if the sustainable development goals (SDGs) will be achieved by 2030. Similarly, though the U5M is on as lightly downward trend in Nigeria from 157, 128, and 132 deaths per 1000 live births in 2008, 2013, and 2018 respectively, about one in six children under the age of five years still die. Therefore the country needs to make progress in the reduction of the under-five mortality in the country for it to achieve the third Sustainable Development Goals (SDG's) targets of great reduction in childhood mortality by 2030(National Population Commission (NPC) [Nigeria] and ICF 2018).

Several models have been used to understand the factors associated with both child and under-five mortality. A study on determinants of child mortality used Logistic regression model and found that Poverty, Malaria, Postnatal care, Health scheme and Breast feeding were major determinants of under-five mortality (Bello and Joseph 2014). Birth spacing, breast feeding, mother's age at birth, mother's educational and smoking status, child's sex were significantly associated with under-five morality (U5M) in a study from Jordan (Kaldewei 2010). Logistic and Probit models were used where Logistic regression was found to be a better prediction of U5M (Kaldewei 2010). Another study on child mortality

from Nigeria used Logistic regression and chi-square test and found parents' education, mother's occupation to be statistically significant determinants of U5M (Adetoro and Amoo 2014). A study in Indonesia employed Weibull hazard model to identify, mothers' factors such as education, working status, astronomy, economic status, maternal age at birth, birth interval, type of births, complications, history of previous mortality, breast feeding, antenatal care and place of delivery as factors associated with under-five mortality. In addition, children of educated rural women survived more than their moral counterpart who were not educated (Warrohmah *et al.* 2018).

In Nigeria, the NDHS 2003, 2008, and 2013 data were analyzed using Cochran-Mantel-Haenzel chi-square statistics and multiple logistic regression. It was observed that Under-five children of mothers who never experienced adverse Pregnancy Outcome had higher risk of mortality than those under-five children of mothers who did (Debem, Refaat, and Osoba 2018). Adedini in his study used Cox proportional regression analysis and found out that ethnicity had significant association with U5M in Nigeria. He found out that under-five children of the Hausa/ Fulani/ Kanuri tribes had higher risk of death than Yoruba tribes, Igbo and minority ethnic groups (Adedini *et al.* 2015). This study which used NDHS 2008 data, provided similar results to a study carried out using NDHS 2003(Fayehun and Omololu 2011). Another study on Nigeria data (2003, 2008) considered neighborhood contexts as factors associated with U5M. Place of residence, regional difference and ethnicity were significantly associated with U5M. The study also revealed that the hazards rate were high among children in the poor and rural neighborhoods and North Eastern region (Adedini *et al.* 2015).

From the above studies in Nigeria, it was observed that many have not described the appropriate models for the identification of risk factors of under-five mortality. Our study therefore aimed at looking at different binomial models for identifying risk factors of under-five mortality. This would help us to identify the appropriate model with their associated factors. Hence, this will help health policy makers to take reasonable decisions in the quest to solve the current situation of under-five mortality in Nigeria.

**Methodology**

This study is a retrospective analysis of secondary data of the Nigerian Demographic and Health Survey 2018 on the factors associated with under-five mortality in Nigeria. This study made use of the Nigeria Demographic and Health Survey (NDHS 2018) data. This is a nationally representative sample of about 42,000 selected households. The population and Housing Census, conducted in 2006 by the National Population Commission (NPC) was used as the sampling frame for the 2018 NDHS. Nigeria is divided into states and each state subdivided into Local Government Areas (LGAs) also each LGA to localities. Each locality was further divided into convenient areas called census enumeration areas (EAS). The EAS are classified into urban and rural areas for a locality of more than 20,000 population as urban areas.

The study for NDHS 2018 was a two stage stratified cluster sampling method. Probability proportional to size selection was used during the first sampling stage. The extensive description of the design and sampling technique are recorded in the NDHS 2018 reports (NDHS, 2018).

Setting: Nigeria was the setting for this study. This is the most populous country in Africa. Majority of the clusters are scattered throughout the country where South-west is one of the highest density areas (Anon 2020a). Considering the National population and housing census of 2006, the population of the country was 140,431,790 with the population of 22,594,767 (16.09%) with 3.2% per annum estimated national growth rate among the under-five children. Ages 5 -19 years were 51,040,749 (36.5%) of the total population(NDHS, 2013).

Nigeria consists of 36 states and Abuja- the Federal Capital Territory. The country is divided into six (6) geo-political zones namely: North- central, North East, North-West, South East, South-South and South-West. The proportion of Nigerians who practice Islamic and Christianity religion is almost equal with majority of the Islams who are in the Northern, Central and South-western Nigeria. Christians are more in some Central states (Plateau and Benue States), the South East and South-South regions. Other traditional religions are also practiced in Nigeria. Few survey in 2009 reported

that 45% of Muslims were in Nigeria but the latter survey in 2011 recorded more (56.8%) Christians than Muslims (41.1%) with the remaining making up the other religion (Anon 2020a).

The current Nigeria population is 206, 256, 256- based on worldometer elaboration of the latest United Nations data, where the estimated at mid-year 206,139,589 people. The population density in Nigeria is 226 per cm2. The total land area is 910,770 km2 (351,650 Sq. miles) More than half of population are in the urban area (52.0%) (Anon 2020b).
The estimated total population in Nigeria was 200 million people in 2019 by census figures and projections from Trading Economics. Reports show that one person in every 43 people in the world is a Nigerian; that is about 2.35% of the world's total population (Anon 2020c)

**Study variables**
Under 5 mortality is defined as the probability of dying between birth and fifth birthday (i.e death between 0 - 59 months old).
The response variable (Y) for this study was whether the child between ages 0 – 59 months. was dead or alive. The independent variables were respondents current age ($X_1$), Region ($X_2$), type of place of residence ($X_3$), woman's highest Educational level ($X_4$), Husband's educational level ($X_5$), Respondents occupation ($X_6$), Husband's occupation ($X_7$), current marital status of the woman ($X_8$), Age of respondent at 1st birth ($X_9$), Religion ($X_{10}$), Birth order number ($X_{11}$), Sex of child ($X_{12}$), Wealth index ($X_{13}$), Type of toilet facility ($X_{14}$) and Breast feeding ($X_{15}$).

**Data Analysis**
Data analysis was carried out using Statistical Package for Social Sciences (SPSS) version 23 and R programming. The response variable Y was categorized into two groups, $Y_1$ and $Y_2$. $Y_1$ was the number of deaths per woman, and $Y_2$ was the number of children that were alive per woman. Grouped binomial model was applied to the data.
Logistic regression (Logit) model, Probit model, Complementary log-log [CLL] model and Zero-inflated Binomial (ZIB) model were considered in this study. Akaike Information Criterion (AIC) and Residual Deviance (RED) were used for model selection. P- value less than 0.05 was considered to be statistically significant when data were fitted into the models.

**Models for the study**
Binomial models Family namely: Logit model, probit model Cloglog model, and Zero-inflated Binomial model were fitted to the data.

**Logit model:**

(Hilbe 2013; Irwin 2005; Oritogun and Bamgboye 2018; Oritogun, Oyewole, and Daniel 2016)

**1. Logit Regression model**

$$\pi = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \ldots \beta_N X_N)}}$$

$$Logit(\pi) = \ln\left(\frac{\pi}{1-\pi}\right) = \sum_{k=0}^{k=n} \beta_k X_{iR} \ldots. \qquad (1)$$

Standard logistic distribution of errors

$$\pi = \beta_0 X_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{15} X_{15} \qquad \ldots. \qquad (2)$$

Where: $\pi$ is the probability of event occurring (death) of U5 children
$1-\pi$ is the probability that the event will not occur
$\beta_0, \beta_1, \beta_2, \beta_3 \ldots \beta 15$ are the model coefficients,
$X_1$, X2, X3 …X15 are the co-variates.

**2. Probit Model**

$\Phi^{-1}(\pi) = \sum \beta_k X_{ik} = Z$

Normal distribution of errors

$\Phi(\pi) = \Phi(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_J X_J)$

Where $\Phi^{-1}$ is the inverse of the normal Cumulative Distribution Function (CDF)

**3. Complimentary log-log: C log-log**

$$P(X) = 1 - e^{[-e^{(\beta_0 + \beta x)}]}$$

Log [-Log (1-π)] = $\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_j X_j$

**4. Zero Inflated Binomial (ZIB)**

For Y= 0 with probability π and Y ~ BI (n,μ) having a probability (I - π). Then Y has a zero inflated binomial distribution, denoted by ZIB (n,μ, π), given as

$$PY(y/n,\mu,\pi) = \pi + (1-\pi)(1-\mu)^n, \qquad if\ y = 0$$

$$PY(y/n,\mu,\pi) = \frac{(1-\pi)n!\mu^y(1-\mu)^{n-y}}{y!(n-y)!} \qquad if\ y = 1,2,3,...$$

Where

$0 < \mu < 1$, and $0 < \pi < 1$

The mean, E (Y) = (1-π) nμ

Variance, Var (Y) = nμ (1 -π) (1-μ+nμπ)

**Model Selection** (Oritogun et al. 2016)(Hu 2007)(Oritogun and Bamgboye 2018).

Akaike Information Criterion (AIC)

AIC = -2L + 2P

Where L is the log likelihood value, an d P is the number of parameters

**Results**

**Model Comparison**

Tables 1-4 show the values of Residual Deviance and AIC of the models used in this study. ZIB model had the smallest Residual Deviance and AIC of 29,865 and 50,854 respectively, followed by C log-log model (33088; 52114), while Probit model had the highest values (33144; 52170). ZIB model seems to be the best model for U5M in Nigeria since it had the smallest RED and AIC.

The parameters of age group (20 – 24 to 40 – 44 years) region, age of respondents at first birth, and birth order for Logit, Probit and C log-log models had negative signs, and so reduce the probability of a woman having U5M.

**TABLE 1a:Estimates of the Models Compared in the Study**

| Parameters | | Logit Estimate(β) | Probit Estimate(β) | C-Log Log Estimate(β) | ZIB Estimate(β) |
|---|---|---|---|---|---|
| Constant | | -2.56*** | -1.48*** | -2.59*** | -2.11*** |
| **Age(yrs):** | 15-19 | Ref. | Ref. | Ref. | Ref. |
| | 20-24 | -0.11 | -0.04 | -0.11 | -0.13 |
| | 25-29 | -0.25* | -0.11* | -0.25** | -0.30** |
| | 30-34 | -0.22* | -0.09 | -0.22* | -0.30** |
| | 35-39 | -0.15 | -0.06 | -0.16 | -0.26* |
| | 40-44 | -0.08 | -0.02 | -0.09 | -0.22* |
| | 45-49 | 0.04 | 0.05 | 0.02 | -0.09 |
| **Region:** | North Central | Ref. | Ref. | Ref. | Ref. |
| | North East | 0.17*** | 0.09*** | 0.16*** | 0.15*** |
| | North West | 0.49*** | 0.27*** | 0.45*** | 0.43*** |
| | South East | -0.05 | -0.03 | -0.05 | -0.08 |
| | South South | -0.17*** | -0.09*** | -0.16*** | -0.20*** |
| | South West | -0.20*** | -0.10*** | -0.19*** | -0.22*** |
| **Place of residence:** | Rural | Ref. | Ref. | Ref. | Ref. |
| | Urban | -0.23*** | -0.12*** | -0.21*** | -0.20*** |
| **Maternal education:** | Higher Educ. | Ref. | Ref. | Ref. | Ref. |
| | No education | 0.15* | 0.06 | 0.15** | 0.17** |
| | Primary | 0.20*** | 0.08** | 0.20*** | 0.19** |
| | Secondary | 0.13* | 0.05 | 0.13* | 0.13* |
| **Paternal education:** | Higher Educ. | Ref. | Ref. | Ref. | Ref. |
| | No education | 0.37*** | 0.20*** | 0.34*** | 0.35*** |
| | Primary | 0.26*** | 0.14*** | 0.25*** | 0.24*** |
| | Secondary | 0.18*** | 0.09*** | 0.17*** | 0.16*** |
| **Maternal occupation:** | Agriculturist | Ref. | Ref. | Ref. | Ref. |
| | Manual work | 0.15*** | 0.08*** | 0.13*** | 0.13*** |
| | Not working | 0.12*** | 0.06*** | 0.10*** | 0.11** |
| | Professional/technical/managerial | 0.22*** | 0.12*** | 0.20*** | 0.18** |
| **Paternal occupation:** | Agriculturist | Ref. | Ref. | Ref. | Ref. |
| | Manual work | -0.04 | -0.02 | -0.04 | -0.03 |
| | Not working | -0.18*** | -0.10*** | -0.16*** | -0.16*** |
| | Professional/technical/managerial | -0.08* | -0.05* | -0.07* | -0.08 |
| | | RED: 33103; AIC: 52129 | RED:33144; AIC: 52170 | RED:33088; AIC: 52114 | RED: 29865; AIC: 50854 |

**RED:** Residual Deviance; **AIC:** Akaike Information Criterion; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

**TABLE 1b: Estimates of the Models Compared in the Study**

| Parameters | | Logit Estimate(β) | Probit Estimate(β) | C-Log Log Estimate(β) | ZIB Estimate(β) |
|---|---|---|---|---|---|
| **Current marital status of Respondent:** Formally married | | Ref. | Ref. | Ref. | Ref. |
| | Married | -0.04 | -0.02 | -0.04 | -0.05 |
| | Never in union | 0.10 | 0.06 | 0.08 | 0.11 |
| **Age of Respondent at first birth:**< 20yrs | | Ref. | Ref. | Ref. | Ref. |
| | 20 – 35 | -0.25*** | -0.13*** | -0.24*** | -0.21*** |
| | >= 36 | -0.59 | -0.26 | -0.57 | -0.50 |
| **Religion:** | Catholic | Ref. | Ref. | Ref. | Ref. |
| | Islam | 0.37*** | 0.19*** | 0.35*** | 0.35*** |
| | Other Christian | 0.20*** | 0.10*** | 0.19*** | 0.22*** |
| | Others | -0.04 | -0.04 | -0.02 | -0.06 |
| **Birth order:**>= 4 | | Ref. | Ref. | Ref. | Ref. |
| | 1 | -0.86*** | -0.43*** | -0.82*** | -0.94*** |
| | 2 -3 | -0.48*** | -0.25*** | -0.45*** | -0.52*** |
| **Sex of child:** | Female | Ref. | Ref. | Ref. | Ref. |
| | Male | 0.00 | 0.00 | 0.00 | -0.01 |
| **Wealth index:** | Middle | Ref. | Ref. | Ref. | Ref. |
| | Poor | 0.10*** | 0.06*** | 0.09*** | 0.09** |
| | Rich | -0.01 | -0.01 | -0.01 | -0.02 |
| **Type of toilet facility:** Flush/Septic tank | | Ref. | Ref. | Ref. | Ref. |
| | No facility | 0.09*** | 0.04* | 0.09** | 0.09* |
| | Pit Toilet Latrine | 0.12*** | 0.06*** | 0.11*** | 0.10** |
| **Breastfeeding:** | Breastfed | Ref. | Ref. | Ref. | |
| | Never breastfed | 0.20*** | 0.11*** | 0.18*** | 0.24*** |
| | | RED: 33103; AIC: 52129 | RED:33144; AIC: 52l70 | RED:33088; AIC: 52114 | RED: 29865; AIC: 50854 |

**RED:** Residual Deviance; **AIC:** Akaike Information Criterion; * = $p$< 0.05; ** = $p$ < 0.01; *** = $p$< 0.001

The interpretation of ZIB model was given more attention in this study because it was the best model of the four studied.

Table 4 shows the estimates and Odds ratio (OR) of ZIB model. The explanatory variables that were significantly associated with U5M were: age, region, residence, highest educational levels of the respondents and the husband, woman's occupation, age of respondent at first birth, religion, Birth order, wealth index, types of toilet and breast feeding. The results showed that women of ages 25 – 44 years had a significant less U5M than those in the age group 15 – 19 years. Women in age group 20 – 24 years experienced 0.88 times U5M than respondents of ages 15 – 19 years ($p$> 0.05). Women in age groups 25 – 29 and 30 - 34 years were 0.74 ($p$<0.01) times respectively, less likely to experience U5M than women in age group 15 – 19 years, while those in age groups 35 – 39 and 40 – 44 years were 0.77 and 0.80 ($p$<0.05) times respectively less likely to experience U5M. Under-five mortality occurred 8.6% ($p$>0.05) less likely in age group 45 – 49 years than the reference age of 15 – 19 years. Under-five children of women in North East (1.16, $p$< 0.01) and North West (1.54, $p$< 0.01) experienced higher death than those from North Central. Children from South East (0.93, $p$> 0.05), South-South (0.82, $p$< 0.01) and South-West (0.80, $p$< 0.01) experienced lower mortality than those from North Central. Under-five children in Urban were 0.82 times ($p$< 0.001) less likely to die than children from rural. Furthermore, children of

women who had no education and primary education experienced death 1.2 times each($p < 0.01$) more likely than women with higher education. Women who had secondary education were 1.14 ($p < 0.05$) times, more likely to experience U5M than those with higher education. Under-five children whose father had no education, primary and secondary level of education were 1.43, 1.27 and 1.18 times ($p< 0.001$) more likely to die respectively than children of fathers with higher education.

Occupation of respondents had 1.14 ($p< 0.001$), 1.11 ($p< 0.01$) and 1.20 ($p< 0.01$) times, more deaths for manual work, not working and professional or technical groups respectively, than the agriculturists. Fathers with manual work (0.97, $p> 0.05$), not working group (0.89, $p< 0.001$) and professionals (0.93, $p> 0.05$) were less likely to experience U5M than their counterpart in Agriculture.

Married women experienced 0.95 times ($p> 0.05$) less U5 deaths than formally married women, whereas, never-in-union experienced 1.12 times ($p > 0.05$) higher U5 deaths, than formally married women.

Respondents whose age at first birth were between 20 – 35 and ≥ 36 years were 0.612 ($p >0.05$) and 0.81 ($p < 0.001$) times less likely to experience U5M than those in age group less than 20 years. U5M occurred among women who were from Muslim and other Christian background, 1.43 ($p< 0.001$) and 1.25 ($p< 0.001$) times respectively, more likely than those from Catholic backgrounds; while women from other religious back ground experienced 0.94 ($p > 0.05$) times less than Catholic women. Women who had birth order of 1 and 2 – 3, experienced 0.39 ($p< 0.001$) and 0.60 ($p< 0.001$) times less U5M, than those with ≥ 4 birth order.

**TABLE 2a: Results Of Zero-inflated Binomial Regression Model On Under-Five Mortality**

| Parameters | | Estimate(β) | Odds Ratio Exp(β) | Std. error | p value |
|---|---|---|---|---|---|
| Constant | | -2.11*** | 0.121 | 0.15 | 0.000*** |
| **Age(yrs):** | 15-19 | Ref. | | Ref. | Ref. |
| | 20-24 | -0.13 | 0.878 | 0.10 | 0.211 |
| | 25-29 | -0.30** | 0.742 | 0.10 | 0.004** |
| | 30-34 | -0.30** | 0.744 | 0.11 | 0.005** |
| | 35-39 | -0.26* | 0.772 | 0.11 | 0.016* |
| | 40-44 | -0.22* | 0.801 | 0.11 | 0.040* |
| | 45-49 | -0.09 | 0.914 | 0.11 | 0.412 |
| **Region:** | North Central | Ref. | | Ref. | Ref. |
| | North East | 0.15*** | 1.157 | 0.04 | 0.000*** |
| | North West | 0.43*** | 1.541 | 0.04 | 0.000*** |
| | South East | -0.08 | 0.926 | 0.05 | 0.112 |
| | South South | -0.20*** | 0.817 | 0.05 | 0.000*** |
| | South West | -0.22*** | 0.802 | 0.05 | 0.000*** |
| **Place of residence:** | Rural | Ref. | | Ref. | Ref. |
| | Urban | -0.20*** | 0.817 | 0.02 | 0.000*** |
| **Maternal education:** Higher Educ. | | Ref. | | Ref. | Ref. |
| No education | | 0.17** | 1.190 | 0.07 | 0.008** |
| Primary | | 0.19** | 1.214 | 0.06 | 0.003** |
| Secondary | | 0.13* | 1.138 | 0.06 | 0.036* |
| **Paternal education:** Higher Educ. | | Ref. | | Ref. | Ref. |
| No education | | 0.35*** | 1.425 | 0.04 | 0.000*** |
| Primary | | 0.24*** | 1.272 | 0.05 | 0.000*** |
| Secondary | | 0.16*** | 1.177 | 0.04 | 0.000*** |
| **Maternal occupation:** | Agriculturist | Ref. | | Ref. | Ref. |
| Manual work | | 0.13*** | 1.139 | 0.03 | 0.000*** |
| Not working | | 0.11** | 1.112 | 0.03 | 0.002** |
| Professional/technical/managerial | | 0.18** | 1.201 | 0.06 | 0.002** |
| **Paternal occupation:** Agriculturist | | Ref. | | Ref. | Ref. |
| Manual work | | -0.03 | 0.966 | 0.02 | 0.131 |
| Not working | | -0.16*** | 0.855 | 0.05 | 0.001*** |
| Professional/technical/managerial | | -0.08 | 0.926 | 0.04 | 0.068 |
| **Residual Deviance:** 29865 ; **AIC:** 50854; | | * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$ | | | |

**TABLE 2b: Results Of Zero-inflated Binomial Regression Model On Under-Five Mortality**

| Parameters | | Estimate(β) | Odds Ratio Exp(β) | Std. error | p value |
|---|---|---|---|---|---|
| **Current marital status of Respondent:** Formally married | | Ref. | | Ref. | Ref. |
| | Married | -0.05 | 0.948 | 0.06 | 0.379 |
| | Never in union | 0.11 | 1.116 | 0.11 | 0.313 |
| **Age of Respondent at first birth:**< 20yrs | | Ref. | | Ref. | Ref. |
| | 20 - 35 | -0.21*** | 0.814 | 0.02 | 0.000*** |
| >= 36 | | -0.50 | 0.607 | 0.34 | 0.147 |
| **Religion:** | Catholic | Ref. | | Ref. | Ref. |
| | Islam | 0.35*** | 1.425 | 0.05 | 0.000*** |
| | Other Christian | 0.22*** | 1.245 | 0.05 | 0.000*** |
| | Others | -0.06 | 0.944 | 0.12 | 0.633 |
| **Birth order:**>= 4 | | Ref. | | Ref. | Ref. |
| | 1 | -0.94*** | 0.391 | 0.08 | 0.000*** |
| | 2 -3 | -0.52*** | 0.596 | 0.04 | 0.000*** |
| **Sex of child:** | Female | Ref. | | Ref. | Ref. |
| | Male | -0.01 | 0.990 | 0.02 | 0.592 |
| **Wealth index:** | Middle | Ref. | | Ref. | Ref. |
| | Poor | 0.09** | 1.092 | 0.03 | 0.002** |
| | Rich | -0.02 | 0.978 | 0.02 | 0.376 |
| **Type of toilet facility:** Flush/Septic tank | | Ref. | | Ref. | Ref. |
| | No facility | 0.09* | 1.099 | 0.04 | 0.011* |
| | Pit Toilet Latrine | 0.10** | 1.110 | 0.03 | 0.002** |
| **Breastfeeding:** | Breastfed | | | | |
| | Never breastfed | 0.24*** | 1.273 | 0.02 | 0.000*** |
| **Residual Deviance:** 29865 ; **AIC:** 50854; | | * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$ | | | |

Male children experience 0.99 ($p > 0.05$) times less mortality than the female ones. Women who were poor experienced 1.09 ($p < 0.01$) times U5M more than the middle wealth index women; while the rich women were 0.98 ($p > 0.05$) times less likely to have U5M than the middle wealth index women. Women who had no toilet facility and pit toilet latrine were 1.10 ($p < 0.05$ ) and 1.11 ($p < 0.01$) respectively more likely to experience U5M than those who had flush/ septic tank type of toilet. Under-five children who were not breast fed were 1.3 ($p < 0.001$) times more likely to experience death than those who were breastfed.

**Discussion**

In this paper, different binomial models were used to identify some factors associated with under-five mortality (U5M) in Nigeria namely: Logit or logistic model, Probit model, Complementary log-log model and Zero-inflated Binomial model. The first three models are single binomial models. These are the family of binomial with different link functions. Zero-Inflated Binomial (ZIB) Model, is a mixture model to capture excess zeros. It consists of two- logit distributions (Rigby and Stasinopoulos 2010).

This study has shown that ZIB was the best model for U5M in Nigeria. The following variables were identified as factors associated with increase in U5M: Region (North), educational level of the respondents and their husbands, women's occupation, Religion, wealth index, types of toilet facilities and breast feeding. Those that inversely affected U5M were age of the respondents, Region (southern), husband's occupation, birth order and sex of child. The results showed that age of respondent were significantly associated with U5M. Women of age 20 - 24 years experienced child mortality lesser than those with ages 15 - 19

years but the effect of the two age groups was not significant. Sometimes, the difference in these two age groups might be in their physical development but in some cases, it is not often pronounced. Generally, there was lower U5M in women that were older than ages 15 - 19 years. It is also showed that as the age of women increase, the percentage of U5M decreased. This was contrary to previous studies that showed that as the age of respondent increased, the U5M also increased (Adebowale, Yusuf and Fagbamigbe, 2012; Kayode, Adekanmbi and Uthman, 2012).

There was significant difference in the U5M of the Northern and Southern women. The North-East and North-West women experienced more U5M than the North Central women. On the other hand, Southern women experienced lower U5M than their counterpart from the North. This result could be attributed to the fact that some mothers in the Northern states got married at a younger age than those in the South, which is related to our results of having U5M more in younger mothers. Other studies have shown that U5M were more among the mothers in the north than south (NDHS, 2013; NDHS, 2018;Adebowale, Yusuf and Fagbamigbe, 2012).

Place of residence was significantly associated with U5M. Women from rural areas experienced U5M than the ones resident in urban areas. This could be possible because of the less exposure of rural women to some social amenities that could prevent mortality. The rural women are less privileged in terms of education, access to primary health care, necessary information about their health and that of their babies. This report was similar to previous study by Kayode and others (Kayode, Adekanmbi and Uthman, 2012; UNICEF, 2015; Kaldewei, 2010; Adedini *et al.,* 2015; NDHS, 2013).

Education of both parents was significantly associated with U5M. The parents who had no education, Primary and Secondary level of education experienced U5M than those with higher level of education. The importance of education has shown here that having being taught brings knowledge and awareness about what is happening around an individual. Education will enable the parents know about the importance of antenatal care, immunization, maternal health during pregnancy, and so on. Also, those who attended school will not get married as teenagers. The result was similar to other studies that education played a key role in preventing U5M (Adebowale *et al.* 2012; Akinyemi, Bamgboye, and Ayeni 2015; Fayehun and Omololu 2011; Warrohmah *et al*. 2018)

Occupation of mothers significantly affected U5M. Those that were not working, doing manual work, professional, were negatively affected than women who engaged in agriculture. This could be as a result of not having time to take care of these children. Surprisingly, those who were not engaged in any occupation (not working) also experience higher U5M than the farmers(Kayode et al. 2012). On the other hand, the occupation of fathers reduced the U5M experience (Adetoro and Amoo 2014). Fathers who were not working at all significantly reduced U5M. It might be that those fathers would have time to assist in taking care of the child.

Current marital status of the respondents did not statistically affect U5M but those that were never-in-a-union experience U5M than the formally married ones. On the other hand, the married respondents experienced lower U5M than the formally married (Adedini *et al.* 2015).Another factor that significantly reduced U5M was the age of respondents at first birth (20 - 35 years) (Fayehun and Omololu 2011; Kayode *et al.* 2012). Women of ages 36 years and above experienced less U5M, than those who were below 20 years of age. The age of a woman at first birth matters a lot since age and body weight or physiological development depends on age (Debem *et al*. 2018).

Mothers with Islamic background and other Christian but not Catholic had more U5M than the catholic mothers. And mothers who practiced other religions had less insignificant U5M than the Catholics. The belief of mothers probably affected their response to the needs of their children. For example, some believe that eating a particular meat, egg or vegetable will affect them in pregnancy. This attitude will hinder them to eat food with vitamins, protein etc, hence endanger the health of the mother and child. Sick mothers cannot take care of her child or breast feed. A study by Adetoro reported that religion had no significant effect on U5M (Adetoro and Amoo 2014).

The position of a child is another important factor of U5M. Birth order of 1 and 2 - 3 children significantly experienced less deaths than 4 and above. In some studies, birth order of 1 had more U5M than 4 and above (Anyamele, Akanegbu, and Ukawuilulu 2015; Ezeh *et al.* 2015; National Population Commission 2013). In this study, child of birth order 1 had less U5M might be due to the fact that the members of the family like mother in-law came around to assist the woman, and other people around by encouraging, reminding her of necessary things to be done like clinic visit, immunization etc. The family of four or more children may be faced with some challenges such as finance, scramble for food etc(Adedini et al. 2015; Kaldewei 2010; Kayode *et al.* 2012).

The sex of the child in this study showed no significant relationship with U5M, though male child experienced less U5M than the female child. Some other studies showed variations in gender (Kaldewei 2010; Moise 2018; UNICEF 2015). Furthermore, wealth index of poor mothers experienced significant higher U5M than the middle index category. The rich mothers had insignificant less U5M. Wealth is very important in life as a wealthy mothers will have money in their possessions to buy and get whatever is needed to take care of their babies (Adetoro and Amoo 2014).Also, types of toilet facilities exposed to by mothers had significant relationship with U5M. Women who were not using flush/ septic tank type of toilet facilities experienced more U5M. (Fayehun and Omololu 2011; Kaldewei 2010)

The last but not the least factor examined in this study was breast feeding. Respondents who breastfed their children experienced less U5M. It is expected that mothers should breastfeed their babies exclusively for the first 6 months. Children who are not properly breastfed will be exposed to different illnesses which will eventually affect the health of the child. Studies have shown that breastfeeding is significantly related to child-hood survival (Bello and Joseph 2014).

## Conclusion

This study revealed that Zero-Inflated Binomial (ZIB) model was the best model for U5M in Nigeria. The model identified region, Maternal and Paternal education level, religion, types of toilet facilities and never-breastfed as the risk factors of U5M. Policy makers should pay considerable attention to address these factors to further reduce the public health challenge of under-five mortality in Nigeria.

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