Annals of Health Research
Volume 4, Issue No 2: 141-154
July-December 2018
DOI: 10.30442/ahr.0402-6-17

ORIGINAL RESEARCH

Robustness of Poisson Mixture models in identifying risk factors for Under-Five mortality in Nigeria

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Abstract

Background: Estimates of Under-Five mortality (U5M) have taken advantage of indirect methods but U5M risk factors have been identified using fixed statistical models with little considerations for the potentials of mixture models. Mixture models such as Poisson-Mixture models exhibit flexibility tendency, which is an attribute of robustness lacking in fixed models.
Objective: To examine the robustness of Poisson-Mixture models in identifying reliable determinants of U5M.
Methods: The data on 18,855 women used in this study were obtained from the 2008 Nigeria Demographic and Health Survey (NDHS). Six different Poisson-Mixture models namely: Poisson (PO), Zero-Inflated Poisson (ZIP), Poisson Hurdle (PH), Negative Binomial (NBI), Zero-Inflated Negative Binomial (ZINBI) and Negative Binomial Hurdle (NBIH) were fitted separately to the data. The Akaike Information Criteria (AIC) and diagnostic check for normality were used to select robust models. All tests were conducted at p = 0.05.
Results: The models and AIC values for U5M were: 38763.47 (PO), 38654.55 (ZIP), 44270.77 (PH), 38526.26 (NBI), 38513.71 (ZINBI) and 44269.30 (NBIH). The PO, ZIP, PH and NBIH met normality test criteria, and the ZIP model was of best fit. The model identified breastfeeding, paternal education, toilet type, maternal education, place of delivery, birth-order and antenatal-visits as significant determinants of U5M at the national level.
***Conclusion*:** The Zero-Inflated Poisson model provided the best robust estimates of Under-five Mortality in Nigeria, while maternal education and birth-order were identified as the most important determinants. The Poisson-mixture models are recommended for modelling Under-five Mortality in Nigeria.

Keywords:* *Akaike Information Criteria, Child mortality, Under-five Mortality, Zero-Inflated Poisson model, Poisson-mixture models, Maternal education

Introduction

The most crucial years for the physical and intellectual development of children occur during their first five years of life. The events that occur during the period can determine their competence to prosper and gain knowledge for life. [1] It means that every single day counts for these children. Globally, approximately 10.5 million children under 5 years of age die every year and about 1.5 to 2.5 million infants die in their first week of life. Eighty-eight per cent of these infant and child deaths occur in developing countries, especially the world's 42 lowest – income countries in sub-Saharan Africa. [2]

Under-five mortality, for the first time in 2006, fell below 10 million, which was 25 per cent decline from the almost 13 million childhood deaths recorded in 1990 [4] (the baseline for the defunct Millennium Development Goals target). In some sub-Sahara African countries, the reduction was very marked, reaching up to 50%, but the fall in U5M was less than 15%. The evidence from literature revealed that there was an increase in Under-Five mortality (U5M) in 2007 and 2011 being 138 per 1,000 live births and 158 per 1,000 live births respectively in Nigeria as against 71 per 1,000 live births which was the MDG target or goal. [5 - 7]

The health of Nigerian children is challenged by such factors that have negative consequences on their survival. Reports have shown that worldwide, factors such as nutritional deficiencies, illnesses, malaria, diarrhoeal diseases, acute respiratory infections (ARI), and vaccine-preventable diseases (VPD) contributed massively to childhood morbidity and mortality. [1,5,8] Maternal morbidity and mortality are not excluded and the effect of the multiplicity of ethnic groups with its attendant cultural differences may be the major contributory factors to the poor survival of Nigerian child. [1] The cultural beliefs and attitudes such as food taboos, gender-related practices (early marriage) and the inability of women to exercise their reproductive right contribute to higher levels of childhood mortality. Other factors include poor access to modern family health care which results in the use of traditional medicine as the first line of treatment for childhood illnesses.

Malaria and diarrhoeal illness are the most common health challenges which significantly contribute to the morbidity and mortality of children under five years of age. Research shows that malaria has the highest contribution to infants' morbidity and mortality in the range of 38% and 28% respectively while its contribution to young children morbidity and mortality were 41% and 30% respectively. This is followed by diarrhoeal diseases which contribute between 28% and 30% [1]. More than 73% of deaths among under-five children were caused by malaria which similarly caused over 10 per cent of maternal deaths, particularly among primigravida women. [1]

It has also been shown that the estimated distribution of the causes of deaths in children aged one to 59 months in sub-Saharan Africa and Southeast Asia included pneumonia, diarrhoea, malaria, injury, meningitis, measles and other causes. Pneumonia and diarrhoea remained the leading causes of death among children aged one to 59 months in sub-Saharan Africa and Southeast Asia. [9]

In an exploratory ecological study on environmental sanitation and mortality, combined with other literature, it was noted that mortality associated with waterborne diseases was inversely related to the level of education; but a direct relationship was observed between inadequate sanitation in the dwelling such as sewage disposal via rudimentary gutters and pits, the disposal of waste in uncultivated land or public areas and the incidence of water-borne diseases. However, general sanitation conditions and other factors related to dwelling quality and infrastructure were major determinants of mortality in the study. [10-13]

Nearly all the reported studies on the factors determining Under-Five mortality relied on univariate analysis of the data and other statistical models like Logistic and Poisson regressions with little considerations for the suitability of these statistical methods. [14-16] This exposes some of the findings to suspicions. Therefore, it is important to use an appropriate robust model that would consider all the socio-demographic characteristics of the women, fertility history and other factors relevant to the survival of the children to actually determine the true picture of the determinants of infants and child mortality.

There are many reports on determinants of Under-Five mortality (U5M) both in Nigeria and outside the country, arising from the application of different chains of Multivariate analysis, and several other statistical methods. This has been facilitated by the availability of numerous on-the- counter statistical computer software packages and growing number of non-professionals who indiscriminately use the package without due consideration to the appropriateness of the statistical model to the data set at their disposal. Some of these analysts often pay less attention to the assumptions underlying the use of these different statistical methods which will eventually affect the interpretation of their results. Consequently, many factors are being suggested and/or identified as determinants of U5M depending on the various statistical methods used in analyzing their data. Therefore, such multiplicity of determinants of Under-five Mortality (U5M) has not enabled policymakers and public health authorities to introduce appropriate and effective intervention strategies to significantly reduce U5M in Nigeria.

None of the previous attempts had combined mixture of models such as Poisson-Mixture Models, the use of Akaike Information Criterion (AIC), and diagnostic check for normality to determine the best model for describing U5M mortality in Nigeria. The use of these mixtures of models would have helped researchers to use count data as response variable rather than categorical response variables that are common in the literature which sometimes results in the loss of information. Therefore, this study examined the performance of some mixture models in the identification of the determinants of U5M, their suitability or appropriateness, and their statistical significance. The best model and identified determinants, peculiar to the National U5M were presented. Consequently, the government will be able to concentrate on the major factors in solving the problem of Childhood mortality in Nigeria. This study was embarked upon to assess the risk factors for U5M in Nigeria using Poisson-Mixture models.

Methods

Study Design/Data collection

The secondary data obtained from the Nigeria Demographic and Health Survey (NDHS) for the year 2008 were analyzed. More information on the data can be found in NDHS, 2009 report and Oritogun *et al.* [13,17]

Statistical Analysis

The statistical software packages used included SPSS (version 20), Microsoft® Excel and R. The models considered included six different Poisson-Mixture models namely: Poisson (PO), Zero-Inflated Poisson (ZIP), Poisson Hurdle (PH), Negative Binomial (NBI), Zero-Inflated Negative Binomial (ZINBI) and Negative Binomial Hurdle (NBIH) were fitted separately to the data. The Akaike Information Criteria (AIC) and diagnostic check for normality such as D'Agostino Skewness test, Lilliefors (Kolmogorov-Smirnov) normality test and Pearson Chi-Square normality test were used to select robust models.

The p-value of 0.05 was considered to be significant. The response variable was the number of children between ages 0 and 59 months which died per woman. The independent variables included: birth order, respondent's age , breastfeeding or not {1=Yes, 2= No }, h father's level of education {0=pry/no formal edu, 1= secondary, 2=higher}, mother's level of education {0=pry/no formal edu,1= secondary, 2=Higher}, type of toilet facility in the household {0= no facility, 1= pit latrine, 2= others, 3= water cistern}, religion {1= Islam, 2= Traditional/others, 3= Other Christians, 4= Catholic), Place of delivery of the baby (1=Government/Public, 2=Home, 3=Private), antenatal clinic visits /attendance (1= Yes, 2= No).

Models for the Study

The models for this study included:: Poisson (PO), Negative Binomial (NBI), Zero-Inflated Poisson (ZIP), Poisson Hurdle (PH), Zero-Inflated Negative Binomial (ZINBI) and Negative Binomial Hurdle (NBIH) were fitted separately to the data. [18 - 21]

1. Poisson (PO) model

(1.1) $\Pr\left[X = r, \lambda\right] = \dfrac{\lambda^{r} e^{-\lambda}}{r!}, \quad r = 0, 1, 2, \ldots$; Where $\lambda > 0$

Mean and variance are equal.

(1.2) $E(X) = Var(X) = \lambda$

(1.3) The link function is given thus: $\xi_i = \log(\lambda_i) \;\; and \;\; \xi_i = X'\beta$

It now becomes,

(1.4) $$\log(\lambda_i) = X'\beta = \beta_0 + \beta_i x_{i1} + \ldots + \beta_p x_{ip}$$

Where $x = (x_1, \ldots, x_k)'$ is a vector of explanatory variables or independent variables as were listed in the study where β_o is the intercept parameter, and β is the vector of slope parameters.

2. *Negative Binomial (NBI) model*

Negative binomial model is used when the property of Poisson model of equal mean and variance does not hold any longer. In this case, there is over-dispersion, where the variance exceeds the mean.

$E(X) = \lambda, Var(X) > E(X)$

The systematic part and link function are:

$\beta_0 + \beta_i X_{ij} \quad and \quad \log$, respectively.

NBI model is:

(2.1) $P(y; \mu, \alpha) = \dfrac{\Gamma(y + \alpha^{-1})}{y!\Gamma(\alpha^{-1})}\left(\dfrac{\alpha\mu}{1+\alpha\mu}\right)^{y}\left(\dfrac{1}{1+\alpha\mu}\right)^{\alpha^{-1}}, \alpha > 0$

(2.2) $\mu_{ij} = \exp\left[\beta_0 + \beta_i X_{ij}\right]$

Parameter α shows the over-dispersion level.

3. *Zero-inflated Poisson (ZIP) model:*

ZIP is a mixture model used to explain excess zeros in the given variable. It has two parts consisting of standard Poisson and the Logit for the zero values. Zero-inflated models recognize two sources of zeros namely structural and sampling zeros.

The model is:

$$\text{(3.1)}\quad \Pr(y_i/x_i)=\begin{cases}\nu_i+(1-\nu_i)\exp(-\mu_i), & y_i=0,\ 0\le\nu_i\le 1\\ (1-\nu_i)\exp(-\mu_i)\mu_i^{y_i}/y_i!, & y_i>0.\end{cases}$$

μ_i and ν_i are the parameters obtained by taking the link functions,

$$\text{(3.2)}\quad \log\mu=Q\beta \quad\text{and}\quad \log\left(\frac{\nu}{1-\nu}\right)=\mathrm{B}\phi$$

Q and B are covariate matrices, β and ϕ unknown parameter vectors.

ν_i represents the probability of the presence of extra zeros.

$$\text{(3.3)}\quad E(Y)=(1-\nu_i)\mu=\lambda.$$

$$Var(Y)=\lambda+\left(\frac{\nu}{1+\nu}\right)\lambda^2$$

4. *Poisson Hurdle (PH) model*

Poisson Hurdle Model, also called Poisson-Logit Hurdle model is a mixture of Poisson and Logit models for count data. Hurdle models assume that all zero data are from one "structural" source while the positive part of the data is from "sampling" source.

PH model is

$$\text{(4.1)}\quad \Pr(Y=0)=1-\nu,\ 0\le\nu\le 1$$

$$\text{(4.2)}\quad \Pr(Y=y)=\nu\frac{\mu^y e^{-\mu}}{y!\left(1-e^{-\mu}\right)},\ \mu>0;\ y=1,2,\ldots$$

μ is the mean of the Poisson structure.

When $(1-\nu)>\exp(-\mu)$, then zero inflation occur relative to an ordinary Poisson.

5. *Zero-inflated Negative Binomial (ZINBI) model*

$$\text{(5.1)}\quad \Pr(y_i/\mu_i)=\begin{cases}\nu_i+(1-\nu_i)(1+\alpha\mu_i)^{-\alpha^{-1}}, & y_i=0,\ 0\le\nu_i\le 1\\ (1-\nu_i)\dfrac{\Gamma(y_i+1/\alpha)(\alpha\mu_i)^{y_i}}{y_i!\,\Gamma(1/\alpha)(1+\alpha\mu_i)^{y_i+\frac{1}{\alpha}}}, & y_i>0.\end{cases}$$

ν_i and μ_i parameters depend on the covariates, where $\alpha\ge 0$ is a parameter for over - dispersion.

6. Negative Binomial Hurdle (NBIH) model

Negative binomial Hurdle model is an alternative to Poisson Hurdle model when the variance exceeds the mean (i.e. overdispersion) in the presence of excess zeros).

(6.1) $$\Pr(Y=0)=1-\rho, \quad 0\le\rho\le1$$

(6.2) $$\Pr(Y=y)=\frac{\rho}{1-\left(\frac{r}{\mu+r}\right)^{r}}\frac{\Gamma(y+r)}{\Gamma(r)y!}\left(\frac{\mu}{\mu+r}\right)^{y}\left(\frac{r}{\mu+r}\right)^{r}, \quad r,\mu>0;\ y=1,2,....$$

The mean and variance of the negative binomial base distribution are given as μ and $\mu(1+\mu/r)$ respectively. It implies that $(1+\mu/r)$ is a measure of dispersion.

Criteria for Model Selection [19, 22-25].

1. Akaike Information Criterion (AIC)

AIC = -2L + 2p

Where L is the log-likelihood value, and p is the number of parameters (Yesilova et al, 2010).

2. D'Agostino skewness test (D'Agostino-Pearson (1973))

The D'Agostino test statistic is as follows: Spiegel and Stephens (1999), D'Agostino *et al*.

The third and fourth standardized moments are used, and denoted as:

$\sqrt{b_1}$ and b_2 for skewness and kurtosis respectively.

$$\sqrt{b_1}=\frac{E(X-\mu)^3}{\left[E(X-\mu)^2\right]^{3/2}}=\frac{E(X-\mu)^3}{\sigma^3}$$

and

$$b_2=\frac{E(X-\mu)^4}{\left[E(X-\mu)^2\right]^{2}}=\frac{E(X-\mu)^4}{\sigma^4}$$

Moment coefficient of skewness given as:

$$a_3=\frac{m_3}{s^3}=\frac{m_3}{\left(\sqrt{m_2}\right)^3}=\frac{m_3}{\sqrt{m_2^3}}$$

$$b_1=a_3^2$$

For a normal curve, a_3 *and* b_1 are zero.

Moment coefficient of kurtosis gives

$$b_2=a_4=\frac{m_4}{s^4}$$

$$=\frac{m_4}{s_2^2}$$

For normal distribution: $b_2=a_4=3$

3. Lilliefors (Kolmogorov-Smirnov) normality test

Standard normal CDF (cumulative distribution function) $\Phi(z)$ is compared with the standardized sample CDF $s(z)$ based on the transformation:

$$Z_i = \frac{x_i - s_m}{s} \quad ,$$

Where s_m = sample mean, s = estimate of population standard deviation.

The relations: $\Phi(z_i) - S(z_i)$ *and* $\Phi(z_i) - S(z_{i-1})$ are used for the Lilliefors test statistic.

4. Pearson chi-square normality test

The Chi-Square test for goodness of fit is as follows:

$$\chi^2 = \sum \frac{(y - \widehat{\mu})^2}{V(\widehat{\mu})}$$

$V(\widehat{\mu})$ = estimated variance function for the distribution concerned.

$\widehat{\mu}$ = fitted values.

If the computed test statistic is large, it implies that the observed and expected values are not close; hence the model is not of good fit to the data ($p < 0.05$).

Results

The results for model comparison for Under-Five mortality are given in Table I. The AIC values for the models are as follows: PO - 38763.47, ZIP - 38654.55, PH - 44270.77, NBI - 38526.26, ZINBI - 38513.71 and NBIH - 44269.3. NBI and ZINBI models did not meet all the three normality criteria ($p < 0.05$). The ZIP model had the smallest AIC value of 38654.55 among the models that met the three normality criteria hence, it is of the best fit.

Table II presents the estimates of the models for Under-Five mortality (U5M). An examination of the coefficients of the six models revealed similar variables were significantly associated with U5M but with different coefficient values. The exceptions occurred in Poisson Hurdle and Negative Binomial Hurdle models where women's education (both primary and secondary) and place of delivery (home) showed no significant association with U5M.

In another scenario, PH and NBIH models showed a significant association between religion (other Christians, traditionalist) and U5M whereas other variables did not. In all, the following variables were not significantly associated with U5M: women's age, father's education (secondary), religion (other Christian, traditionalist) and place of delivery (public/government).

Table III shows the risk ratios of the variables when ZIP, the model of best fit was examined. Each additional child in birth order was associated with an estimated 30% increase in U5M. Children who were breastfed experienced a 26% increase in U5M than those who were not breastfed. A one–kg increase in body weight was associated with an estimated 0.1% decrease in U5M. Children whose mothers and fathers had primary or no education experienced about

25% and 64% U5M than those who had higher education respectively. Women with secondary education experienced 33% higher U5M than those with higher education.

Table I: Model comparison using Akaike's Information Criterion (AIC) and Specialized Tests for Goodness of Fit for Under-Five mortality

Models	AIC	P-values for normality tests		
		D'Agostino	Lilliefors	Pearson Chi-Square
PO	38763.47	0.2906	0.4324	0.3952
ZIP	38654.55*	0.5498	0.9191	0.8495
PH	44270.77	0.4010	0.1130	0.3250
NBI	38526.26	0.0050	0.0161	0.1750
INBI	38513.71	0.0263	0.0013	0.0222
NBIH	44269.3	0.2150	0.1274	0.3631

***Smallest AIC when the model met the three normality tests ($p < 0.05$)**

Furthermore, the results showed that children from houses with no toilet, pit latrine, and other types of toilet that were not modern, had U5M of 18%, 23% and 26% higher than those with water closet system or flush type of toilet respectively.

In addition, Muslims experienced 9% U5M higher than women who were Catholics. In addition, mothers who delivered at home experienced 11% higher U5M than those who delivered at private hospitals. Mothers who attended regular ante-natal clinics had 6% less U5M than those who did not attend.

Figure 1 shows the graphical illustration of the results of the normality test for the ZIP model which was of best fit. The density plot of residual shows a bell shape, a characteristic feature of a normal distribution. The Q-Q plot gives an indication of normally distributed residuals as no point was found outside the line of equal distribution.

Discussion

This study used Poisson-Mixture models in the analysis of the data contrary to previous studies on Under-five mortality. The previous studies considered and employed statistical models/methods that do not involve a mixture of models. The use of categorical regression models in the study of U5M may undercount the average number of deaths per woman since multiple incidences are collapsed into a single unit in order to meet the condition for use of logistic regression. [26,27] Therefore, it is an indication that these conventional models (categorical regression models) lack predictive ability coupled with low level of robustness in describing the contributions of the determinants of U5M as they are outperformed by Mixture Models.

In this study, the Zero-Inflated Poisson (ZIP) model was of the best fit based on a diagnostic check for normality test for Under-Five mortality. The finding is an indication that there were excess zero counts in the data, which were due to both structural and sampling zeros. This showed that the Poisson mixture models performed better than other models in determining factors associated with Under-Five mortality in Nigeria.

Table II: Model estimates of the best model (ZIP) and other models for National Under-five mortality

Variables & Intercepts		PO β	ZIP B	PH β	NBI β	ZINBI B	NBIH β
Intercept		-2.5105	-2.4836	-1.7852*	-2.5557*	-2.5423*	-1.8206*
Birth order		0.2676*	0.2645*	0.2084	0.2867*	0.2850*	0.2118*
Respondent's Age		-0.0002	0.005	0.0023	-0.0019	-0.00017	0.0023
Breastfeeding	Yes	0.2350*	0.2323*	0.1545*	0.2529*	0.2515*	0.1561*
	No**						
Father's education	Primary/None	0.2014*	0.1915*	0.1606*	0.2040*	0.2010*	0.1630*
	Secondary	0.0665	0.0597	0.00004	0.0759	0.0734	0.0027
	Higher**						
Mother's education	Primary/None	0.4827*	0.4938*	0.1832	0.4700*	0.4725*	0.1838
	Secondary	0.2770^	0.2847*	0.0579	0.2697*	0.2714*	0.0579
	Higher**						
Toilet type	None	0.1661*	0.1691*	0.1842*	0.1544*	0.1564*	0.1838*
	Pit latrine	0.2306*	0.2312*	0.1755*	0.2295*	0.2301*	0.1752*
	Others	0.1869*	0.2062*	0.2096*	0.1928*	0.1987*	0.2120*
	Flush**						
Religion	Islam	0.0803*	0.0868*	0.2713*	0.0792*	0.0824*	0.2748*
	Traditionalist/Others	-0.0072	-0.0010	0.1769*	-0.0261	-0.0219	0.1767*
	Other Christians	0.0127	0.0163	0.1177*	0.0174	0.0186	0.1195*
	Catholics**						
Place of delivery	Government/Public	-0.0522	-0.0527	-0.0238	-0.0652	-0.0642	-0.0261
	Home	0.1018*	0.1041*	0.0786	0.0952*	0.0961*	0.0767
	Private**						
Antenatal clinic attendance	Yes	-0.0639*	-0.0605*	-0.0732*	-0.0556*	-0.0552*	-0.0730
	No**						

Significant at P-value < 0.05;**   * Reference group**

This was a great improvement over the previous studies where single models were used for modelling Under-Five mortality (U5M). This model allows the identification of the true nature of the data which ordinary single model, especially binary models, will not show. This has been achieved as a result of the flexibility and robustness of this model. This observation agreed with a report by Zorn that used Zero-Inflated and Hurdle Poisson models to determine the factors associated with congressional responses to Supreme Court decisions. [28]

The model identified birth order to be positively associated with U5M. There was a 30% increase in mortality for one additional increase in birth order. Mortality increased with increasing birth order. Probably, this may be due to less attention given to children of higher birth order. In fact, birth order had a significant positive association with U5M in all the models.

Table III: Incidence Rate Ratios (IRR) of the best models for National Under-five mortality

Variables & Intercepts		**Under-Five mortality ZIP**
Intercept		0.083*
Birth order		1.303*
Respondent's Age		1.001
Breastfeeding	Yes	1.261*
	No**	
Father's education	Primary/None	1.211*
	Secondary	1.062
	Higher**	
Mother's education	Primary/None	1.639*
	Secondary	1.329*
	Higher**	
Toilet type	None	1.184*
	Pit latrine	1.229*
	Others	1.260*
	Flush**	
Religion	Islam	1.090*
	Traditionalist/Others	0.999
	Other Christians	1.016
	Catholics**	
Place of delivery	Government/Public	0.949
	Home	1.110*
	Private**	
Antenatal clinic attendance	Yes	0.941*
	No**	

***Significant at P-value < 0.05; ** Reference group**

This makes it a factor which cannot be ignored in reducing U5M in Nigeria. The result is similar to the work of Izugbala and Kayode *et al* where birth order showed a positive significant association with U5M. [29,30] However, Fayehun showed that children with birth order of three or more experienced high childhood mortality but this was not statistically significant. [31]

An amazing result occurred between breastfeeding and U5M. Under-Five children who were breastfed experienced a 26% increase in U5M compared with those who were not breastfed. This could have happened if the women were practising mixed feeding instead of exclusive breastfeeding which may have predisposed the children to ingestion of contaminated feeds. This result negates the finding of Rajvir *et al*, [32] which claimed that breastfeeding reduced U5M.

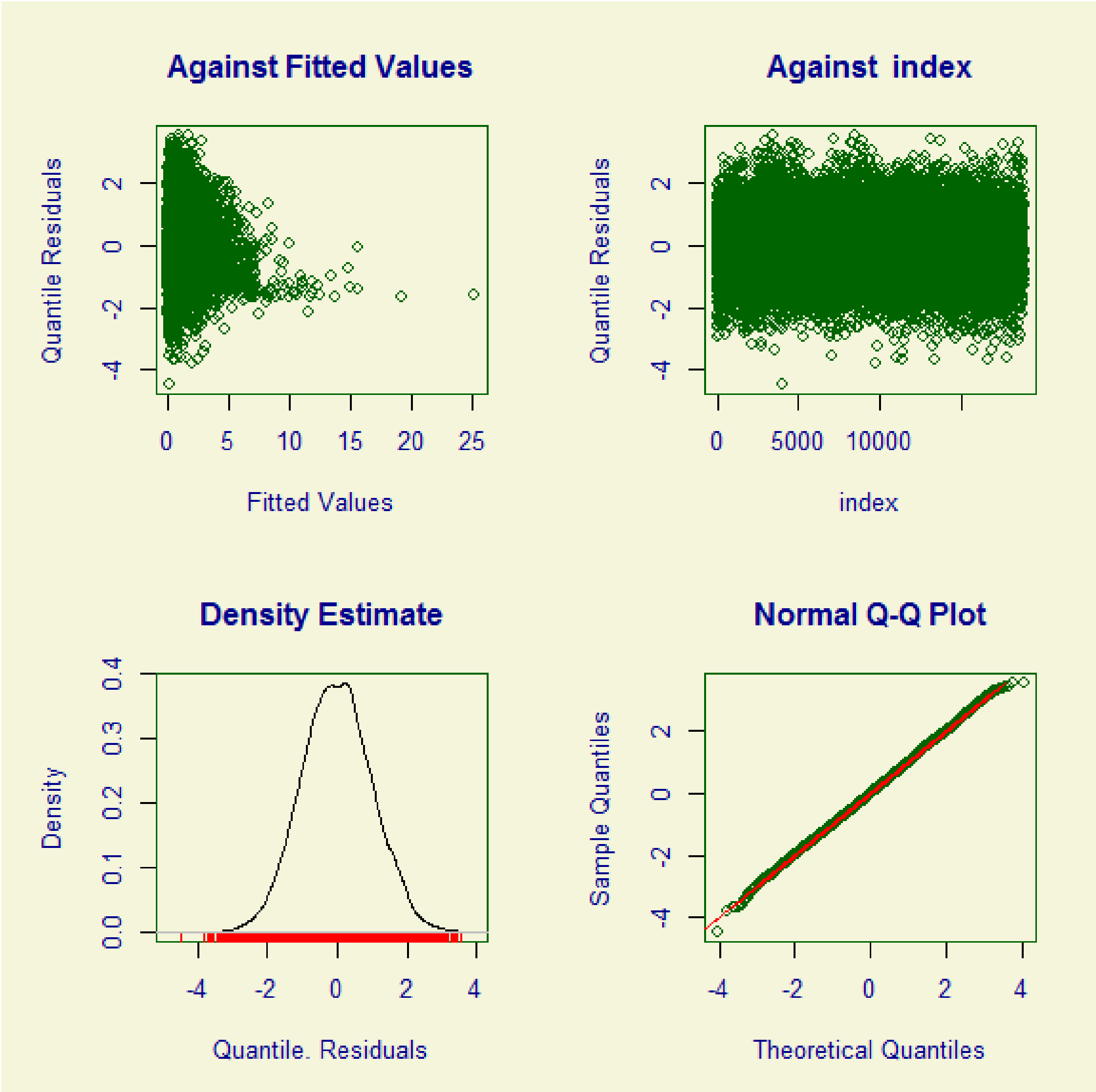

Figure 1: Zero-Inflated Poisson model for National U5M

The fathers' and mothers' educational attainments had a significant association with U5M. Parents with no education or primary education experienced higher mortality than those with higher education. This study showed that fathers and mothers with no education experienced about 25% and 64% U5M higher than those who had higher education respectively. The level of education of the mothers is more important than that of fathers since the women with secondary education experienced 33% higher U5M than those with higher education while having secondary education by fathers was not significantly associated with U5M. Consequently, the education of both parents will afford them the opportunity to know about health care services including the importance of antenatal care, immunization, breastfeeding and nutrition. Other studies have shown that mothers and fathers with no education or primary education experienced more U5M compared with those who had higher education. Fathers with junior high school education are less likely to experience U5M than mothers with no formal education at all. [33 - 35]

Furthermore, the results showed that U5M occurred among children from houses with no toilet (18%) and pit latrine (23%) compared with water cistern or flush types of toilet. Availability of modern toilet may reduce contact with microbes and improve personal hygiene. This conforms to the findings of Kayode *et al* that non-sanitary toilet facility had a significant positive association with U5M. [30] In addition, Muslims experienced 9% U5M more than Catholics. Other religions had no significant association with U5M. This is similar to the findings in a study where religion was significantly associated with U5M and influenced by the characteristics of the community. [36] It also showed that traditional religion was associated with U5M in contrast to the findings in the present study.

Women who delivered their babies at home also experienced higher (11%) mortality than those delivered at private hospitals. Skilled health personnel will be available at the private hospital to assist during delivery compared to when delivery took place at home. Rajvir *et al* made similar reports that hospital delivery reduced U5M compared to no care, and home delivery. [32] Finally, regular antenatal visits had less U5M of about 6% than those who did not attend antenatal clinics. An adequate number of antenatal visits will enable the woman to get information about her personal health and the health of the child. A previous study agreed with this observation that antenatal clinic visits increased under-five survival. Such visits will ensure information complications in pregnancy are discussed with the women. [32]

Conclusion

The Zero-Inflated Poisson model provided the best robust estimates of Under-Five mortality in Nigeria. The use of both AIC and normality test criteria have assisted in identifying an appropriate model for describing U5M in Nigeria. Maternal education and birth order were identified as the most important determinants of U5M. Therefore, the Poisson-mixture models are recommended for modelling Under-Five mortality in Nigeria. The models employed in the present study are robust to criterion assumptions (criterion robustness).

Acknowledgement: The authors acknowledge and show our appreciation to the ORC Macro International, and National Population Commission, Abuja, Nigeria for the permission to use the 2008 NDHS data.

Authors' Contributions: Both authors conceived and designed the study. OKS analysed the data and wrote the first draft. BEA revised the draft and made a substantial impact on the intellectual contents of the manuscript.

Conflict of interest: None declared.

Funding: Self-funded.

Publication History: Submitted 24 April 2018; Revised 29 May 2018; Accepted 18 June 2018.

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