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MODELING OF FACTORS RESPONSIBLE FOR CHILD'S MORTALITY IN THE NORTH CENTRAL NIGERIA.

By

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Abstract

The study examines factors that are responsible for child mortality in the North Central Nigeria, with intention to get the best model that can handle mortality data and identify the most parsimonious factors associated with child's mortality in that region. Questionnaires method was adopted to collect information from the respondents. The study utilized frequency and percentage for descriptive analysis, while Zero Inflated Negative Binomial regression was applied for inferential analysis. R programming package V.4.1.2 was used for data analysis, and results were deemed statistically significant at $P < 0.05$. The results revealed that factors such as household wealth, maternal education, healthcare access and water source significantly influenced child mortality rates. The Nigerian Government should recognize poverty as a multidimensional issue that affects not only economic stability but also public health. Consequently, addressing poverty requires prioritized attention and strategic interventions.

Keywords: Mortality, Parsimonious, Zero Inflated distribution, factors, Negative Binomial

Introduction

Child mortality remains a pressing global health concern, with various factors contributing to its prevalence. Statistical modeling plays a crucial role in understanding the complex relationships between these factors and child mortality outcomes. By identifying key determinants, policymakers and healthcare professionals can develop targeted interventions to reduced child's mortality rates.

Child mortality remains a significant public health concern in Nigeria, particularly in the North Central region. Despite efforts to reduce it, the region continues to record high rate of under-five deaths. According to the 2018 Nigeria Demographic and Health Survey (NDHS), the North central region has an under-five mortality rate of 157 deaths per 1000 live births, which is higher than the national average.

The world health organization (WHO) highlights that child mortality can be influenced by various determinants, including maternal education, access to healthcare services, nutritional status, and social-economic conditions (WHO, 2019). In Nigeria, factors such as poverty, inadequate healthcare infrastructure, and cultural practices have been identified as significant contributors to high mortality rates among children under five (National Bureau of Statistics, 2017).

This research seeks to explore the various factors contributing to child mortality in North central Nigeria, focusing on the interplay between social-economic condition, demographic, healthcare-related, and environmental factors. By employing a comprehensive approach to modelling these factors, this work aims to provide insights that can inform policy and intervention strategies. Understanding the factors responsible for child mortality in this region is crucial for developing effective interventions and policies to reduce child mortality.

Modelling factors responsible for child mortality in the North Central Nigeria, involves a multifaceted approach that draws from various disciplines, including public health, sociology, economics, statistics, and environmental science. Nigeria has one of the highest child mortality rates in the world. According to the World Bank and UNICEF, the under-five mortality rate in Nigeria is significantly above the global average.

Global reports, including those from Nigeria and sub-Saharan Africa, indicate that under-five mortality rates (U5MR) remain alarmingly high (Adeboye et al., 2016). In Nigeria, significant regional disparities exist, with U5MR estimates ranging from 128 deaths per 1000 live births in 2013 (Yaya et al., 2017) to 132 deaths per 1000 live births.

According to recent global estimates, Nigeria accounted for a staggering 0.858 million deaths among children under 5 in 2019, the highest absolute number worldwide (Ezeh et al., 2022). Despite concerted national and international efforts to reduce child mortality, Nigeria still falls short of meeting the Sustainable Development Goals (SDGs) target of 25 deaths per 1000 live births by 2030. The Nigerian healthcare system is severely strained, especially in rural regions, by insufficient medical infrastructure, personnel shortages, and antiquated equipment (Welcome, 2011)

Research on child mortality in Nigeria has identified various influential factors. Studies by Kandala et al. (2007) and Ayotunde et al. (2009) highlighted the role of environmental factors. Fasina (2015) found significant associations between household environmental factors, such as water source, toilet type, child stool disposal, and bed net use, and child morbidity and mortality. Other research, including Edeme et al. (2015) and Adeolu et al. (2016), confirmed environmental factors as determinants of child mortality. Additionally, housing materials has been linked to child mortality (Adebowale et al., 2017; Jacob et al., 2011). Cultural practices and perceptions of illness also impact child health (Yildiz, 2018), while ethnic disparities in child mortality risk have been observed, particularly in Northern Nigeria.

Therefore, this study aimed to determine various factors responsible for child mortality and also to investigate the most parsimonious factors responsible for child's mortality.

Materials and Methods

Source of data

The data used for this study were obtained from the field by the researchers. A total of 12,000 Questionnaires were design and administered to all states comprises of North central Nigeria (Kogi, Kwara, Plateau, Niger, Nassarawa, Benue and FCT) and 10,500 were properly filled and returned representing 88% of the total administered questionnaires.

Study Variables

The outcome variables is the Child mortality, while the independent variables are sex of child, age of child, maternal age, place of residence, states, mother's Education, wealth index, source of water, Use of mosquito, place of child birth, Distance to healthcare facility, place of treatment.

Methods of data analysis

Poisson (P) regression Model

For modeling count data, the Poisson distribution is a fundamental and widely used model, characterized by the probability density function:

$$f(x_i;\lambda) = \frac{\exp(-\lambda)\lambda^{x_i}}{x_i!} \qquad (1)$$

Negative binomial (NB) regression model For count data exhibiting over-dispersion, the negative binomial distribution offers a viable modeling option for distribution $\frac{y_i}{x_i}$ which can arise as a gamma misture of poisson distributions. The probability Density function for NB is given by:

$$f(y_i\,;\mu,\theta) = \frac{\Gamma(y_i\ +\ \theta)}{y_i!\,\Gamma(\theta)}.\left(\frac{\theta}{\mu+\theta}\right)^{\theta}\left(\frac{\mu}{\mu+\theta}\right)^{y_i} \qquad (2)$$

With mean μ and shape parameter θ; $\Gamma(.)$ Is the gamma function.

Zero Inflated models

When Poisson and Negative Binomial models encounter datasets with excessive zeros, parameter estimates can be compromised. Zero-inflated models, such as Zero Inflated Poisson (Lambert, 1992) and Zero Inflated Negative Binomial, offer a potential solution to this problem, as explored by researchers like Leoys et al. (2012).

Zero Inflated Poisson (ZIP) Regression

The Zero Inflated Poisson (ZIP) regression model is employed for count data characterized by over dispersion and excess Zeros. This model combines the Poisson distribution (for non-zero counts) with a logit distribution (for excess Zeros). The ZIP model account for two types of Zeros: structural Zeros (from the logit part) and sampling Zeros (expected under a Poisson distribution).

$$P(Y_i = y_i) = \pi_i + (1 - \pi_i)\exp(-\mu_i) \qquad if\ y_i = 0$$

$$P(Y_i = y_i) = (1 - \pi_i)\frac{\exp(-\mu_i)\,\mu_i^{y_i}}{y_i!} \qquad if\ y_i > 0 \tag{3}$$

$0 \leq \pi_i < 1$ is a proportion and $E(Y_i) = (1 - \pi_i)\mu_i$ and $Var(Y_i) = (1 - \pi_i)\mu_i((1 - \pi_i, \mu_i)$ as the conditional expected values and variance of y_i respectively.

Zero Inflated Negative Binomial (ZINB) regression

The Zero Inflated Negative Binomial (ZINB) model is specifically designed for count variables with excess zeros, often arising from over dispersed data. Theoretically, ZINB accounts for two distinct processes: one generating the excess zeros and another producing the count values, allowing these zeros to be modeled independently. The ZINB model can be written as:

$Y_i = 0, \quad with\ Probability\ \ \pi_i$

$Y_i \sim NB(\mu_i, k)$ With Probability$(1 - \pi_i)$, so that

$$\Pr(Y_i = 0) = \pi_i + (1 - \pi_i)(1 + k\mu_i)^{-1/k}$$

$$\Pr(Y_i = y_i) = +(1 - \pi_i)\frac{\Gamma(y_i + 1/k)(k\mu_i)^{y_i}}{\Gamma(y_i + 1)\Gamma(1/k)(1 + k\mu_i)^{y_i + 1/k}}, \quad y_i = 1, 2, \ldots. \tag{4}$$

Where the mean and variance of the Y_i are:

$E(Y_i) = (1 - \pi_i)\mu_i$

$Var(Y_i) = (1 - \pi_i)\mu_i(1 - \mu(\pi_i + k))$

Where μ_i the mean of the underlying negative binomial distribution and k is the over-dispersion parameter.

$Y_i =$ The number of Child's mortality

$X_{1,} X_{2,} \ldots, X_n =$ Selected Independent variables.

Model Selection

The Akaike Information Criterion (AIC), developed by (Akaike, 1973), is a widely used metric for model comparison and selection. The AIC formula is defined as AIC = - 2L +2K, where L is the Log-likelihood and K is the number of Parameters. When comparing models, the one with the lowest AIC is preferred. AIC facilitates comparison of non-nested models fitted to the same data via maximum likelihood, rewarding good fit while penalizing complexity to promote parsimony.

Statistical Analysis

The Analytical approach of descriptive statistics (frequency and percentage) and inferential statistics (Zero Inflated Negative Binomial), implemented in R version, 4.1.2. A significance threshold of P < 0.05 was used.

Table I: Socio – demographic characteristics of the respondents

FACTORS	CATEGORIES	FREQUENCY	PERCENTAGES
Sex of Child	Male	5345	50.9%
	Female	5155	49.1%
Age of Child	< 12 months	2100	20%
	12 – 36 months	4252	40.5%
	37 – 59 months	4148	39.5%
	Total		
Maternal Age	15 – 19 years	452	4.3%
	20 -24 years	2047	19.5%
	25 – 29 years	2929	27.9%
	30 – 34 years	2362	22.5%
	35 – 39 years	1691	16.1%
	40 – 44 years	746	7.1%
	45 – 49 years	273	2.6%
	Total	**10,500**	**100%**

Place of Residence	Urban	3623	34.5%
	Rural	6877	65.5%
	Total	**10,500**	**100%**
States	Kogi	1606	15.3%
	Kwara	1407	13.4%
	Niger	1627	15.5%
	Nassarawa	1481	14.1%
	Benue	1701	16.2%
	Plateau	1502	14.3%
	FCT Abuja	1176	11.2%
	Total	**10,500**	**100%**
Wealth Index	Poorest	2499	23.8%
	Poorer	2393	22.8%
	Middle class	2216	21.1%
	Richer	1911	18.2%
	Richest	1481	14.1%
	Total	**10,500**	**100%**
Source Of Water	Well	3182	30.3%
	Borehole	1900	18.1%
	Water Vendors	1806	17.2%
	River/Stream	1712	16.3%
	Tap	1900	18.1%
	Total	**10,500**	**100%**
Healthcare Access	Hospital	3307	31.5%
	Pharmacy	2457	23.4%
	Dispensary	1617	15.4%
	Spiritual Homes	1533	14.6%
	Traditional Homes	1586	15.1%
	Total	**10,500**	**100%**
Maternal Education	No Education	2446	23.3%
	Primary Education	2667	25.4%
	Secondary Education	2006	19.1%
	Tertiary Education	2247	21.4%
	Others	1134	10.8%
	Total	**10,500**	**100%**

Table 2: Number Childs Mortality

Numbers of deaths	Frequency	Percentages
0	6782	64.6%
1	2065	19.7%
2	956	9.1%
3	385	3.7%
4	165	1.6%
5	74	0.7%
6	40	0.4%

7	15	0.1%
8	13	0.1%
9	3	0.0%
10	2	0.0%
Total **Mean** **Variance**	**10,500** **0.6341** **1.2423**	**100%**

Table 3: Model Selection

MODEL	AIC
Poisson (P) regression	173556
Negative Binomial (NB) regression	173541
Zero Inflated Negative Binomial (ZINB) regression	**169770****
Zero Inflated Poisson (ZIP) regressions	173740

Table 3 reveals that Zero Inflated Poisson (ZIP) regression, Poisson (P) regression and Negative Binomial (NB) models exhibit poor fit, with high AIC values. In contrast, the Zero Inflated Negative Binomial (ZINB) model demonstrates superior performance, boasting the lowest AIC value of 169770. Consequently, the ZINB model is deemed the best fit for the data, and its results are used to interpret the determinants of child's mortality in North Central and Nigeria at large, aligning with established model selection practices (Bamigbala et al., 2016).

Table 4: Estimated Coefficients for Zero Inflated Negative Binomial (ZINB) for Child's Mortality in North Central Nigeria.

Pearson residuals:

Min	1Q	Median	3Q	Max
-1.514	-0.8546	-0.1945	0.8406	1.6135

Count model coefficients (negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.83056	0.00678	122.503	< 2e-16 ***
Wealth Index	-0.13935	0.01117	-12.473	< 2e-16 ***
Source of Water	-0.03134	0.01100	-2.849	0.00438 **

Healthcare Access	-0.13773	0.01155	-11.921	< 2e-16 ***
Maternal Education	-0.19188	0.01139	-16.843	< 2e-16 ***
Log(theta)	17.87556	1.14346	15.633	< 2e-16 ***

Zero-inflation model coefficients (binomial with logit link):

	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	-13.40	11.48	-1.167	0.243
Wealth Index	11.39	11.48	0.992	0.321
Source of Water	12.12	11.48	1.056	0.291
Healthcare Access	12.06	11.48	1.051	0.293
Maternal Education	11.17	11.48	0.973	0.331

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

AIC = 169770

Results and Discussion

The socioeconomic profile of the respondent is detailed in Table 1. Of the 10,500 child's mortality data collected, males accounted for 50.9%, while 49.1% were female. Regarding the age of the respondents, 4.3% falls in the age bracket of 15-19, 19.5% are between 20-24 ages, 27.9% were in 25-29, 22.5% belongs to age group 30-34, 16.1% belongs to age group 35-39, and 7.1% belongs to age group 40-44, while 2.6% of the respondents belongs to age group 45-49.

The sample distribution shows that 34.5% of respondents reside in urban areas, while 65.5% live in rural areas. Regionally, 15.3% are from Kogi state, 13.4% are from Kwara State, 15.5% are from Niger, 14.1% are from Nassarawa,, 16.2% are from Benue and 11.2% are from FCT.

Regarding Mothers' educational background 45.4% have no formal education, 15.5% have primary education, 31.3% have secondary education, and 7.8% have tertiary Education.

The wealth distribution indicates that 23.8% are from the poorest Households, 22.8% are from the poorer households, 21.1% are from the middle class households, 18.2% are from the richer households, while 14.1% are from the richest households.

Based on maternal Education, distribution indicates that 23.3% of the respondents has no formal Education, 25.4% had Primary Education, 19.1% had Secondary Education, and 21.4% had Tertiary Education, while 10.8% of those respondents had other types of Education.

On healthcare access by both mothers and children, distribution reveals that 31.5% of the respondents used Hospital as place for treatment self and children, 23.4% used Pharmacy, 15.4 used Dispensary, and 14.6 visits spiritual homes to take treatment for self and children, while 15.1% of the respondents used traditional homes.

The distribution of child mortality on the basis of source of water availability to households indicates that 30.3% uses Well as Source of water, 18.1% relies on Borehole, 17.2% visits water vendors, and 16.3% visits Rivers/Stream, while 18.1% relies on Tap water.

The distribution of child's mortality in Table 2 reveals a high proportion of zeros (64.6%), indicating excess zeros. The data consists of non-negative integer values. Notably, the variance (1.2423) exceeds the mean (0.6341), suggesting over-dispersion. Hence, the need for other models like Zero Inflated Poisson (ZIP), Zero Inflated Negative Binomial (ZINB), Negative Binomial (NB), Hurdles Poisson, and Hurdles Negative Binomial models.

Conclusion and Recommendations

This research investigated the determinants of child's mortality in North Central Nigeria. Results shows that the best model for the datasets is Zero Inflated Negative Binomial (ZINB, with the least AIC. Also, the results revealed that factors such as household Wealth Index, maternal education, healthcare access and water source significantly contributed to child mortality rates in North

Central Nigeria. This is evidence in Table 4. as all the probability values of factors considered are less than 0.05.

The Nigerian Government should recognize poverty as a multidimensional issue that affects not only economic stability but also public health. Consequently, addressing poverty requires prioritized attention and strategic interventions. Furthermore, additional research is warranted in the Northern region to uncover underlying causes of child mortality, enabling targeted interventions and policy refinements.

Investing in women's education and skill development can have a dual impact: reducing child's mortality and empowering women economically and socially. This empowerment enables women to better support their families, enhance their self – esteem, and take charge of their health. Promoting prenatal care and regular check-ups for older mothers is crucial, potentially leading to improved health outcomes and decreased child mortality.

Government across all tiers should prioritize investments in critical infrastructure, such as safe water sources, sanitation facilities, and drainage systems, to reduce child mortality rates and promote public health.

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