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Full Length Research Article

PROGNOSTIC REGRESSION MODELING OF UNDER-FIVE MORTALITY: EVIDENCE FROM COMMUNITY-LEVEL DATA IN LAGOS STATE, NIGERIA

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ABSTRACT
Under-five mortality remains unevenly distributed across communities in developing economies, reflecting disparities in socioeconomic conditions, maternal characteristics, and access to basic health services. This study examines the determinants of under-five mortality across five administrative divisions of Lagos State, Nigeria, using a prognostic regression framework that aligns with the distributional properties of mortality data. The primary outcome was the number of under-five deaths experienced by a woman, while a secondary outcome captured whether any under-five death occurred. Explanatory variables included socioeconomic status, maternal education, healthcare access, nutritional status, sanitation, immunization coverage, and community of residence. Binary logistic regression was used to model the probability of experiencing any under-five death, while Gaussian and Gamma regression models were applied to mortality severity. Model selection using Akaike and Bayesian Information Criteria identified the Gamma regression model as most appropriate. Results indicate that improved socioeconomic status reduced expected under-five mortality by approximately 68%, while enhanced healthcare access and sanitation reduced mortality by about 57% and 49%, respectively. Each additional year of maternal education reduced expected mortality by about 6%, whereas poor nutritional status significantly increased risk. Marked spatial disparities were observed, with Ikorodu, Badagry, and Epe exhibiting higher mortality burdens. Overall, the findings reveal the importance of distribution-aware prognostic modeling and targeted community-specific interventions to reduce under-five mortality in Lagos State.

Keywords: Under-five mortality; Gamma regression; prognostic modeling; maternal education; healthcare access; Lagos State

INTRODUCTION
Under-five mortality remains a major public health challenge in many low- and middle-income countries. Despite progress in immunization, maternal care, and child-health programs, large inequalities persist within countries and across sub-national communities, driven by socioeconomic deprivation, maternal factors, and uneven access to services. In Nigeria, variations in child survival persist across geographic locations, maternal characteristics, and socioeconomic conditions, reflecting deep-rooted inequalities in access to health-enhancing resources and services. Empirical studies report substantial differentials in child survival across regions and household strata, with children born into disadvantaged households experiencing higher mortality risk (Aigbe & Zannu, 2012). Contextual influences—such as local healthcare infrastructure, environmental sanitation, and maternal education—also shape survival outcomes (Adekanmbi, 2015).
From an analytical standpoint, prognostic modeling provides a structured approach for estimating the probability or expected burden of an outcome based on observed predictors, supporting risk stratification and policy targeting (Abu-Hanna & Lucas, 2001). In under-five mortality studies, regression frameworks are frequently applied to quantify associations between mortality outcomes and maternal, socioeconomic, and contextual factors. However, under-five mortality outcomes often exhibit distributional features—skewness, heterogeneity, and non-constant variance—that can undermine inference if ignored Cameron & Trivedi, 2013). Akanji et al. (2023) focused their research on the rising child mortality rates in Lagos State by employing prognostic models, specifically Prognostic Logistic, Linear, and Poisson regression models. They developed six models from these approaches, which were instrumental in identifying communities in Lagos State with high childhood mortality.
Recent methodological developments emphasize the importance of selecting models that align with the statistical properties of health outcome data. When the response variable is skewed, distributional assumptions and transformation strategies play a crucial role in achieving reliable inference (Arowolo et al., 2019). This motivates careful alignment of model choice with the properties of the outcome.
This study examines under-five mortality across five administrative divisions in Lagos State using a prognostic regression framework with two complementary outcomes: whether a respondent experienced any under-five death and the number of under-five deaths experienced. By comparing logistic regression with continuous-outcome baselines and Gamma regression for skewed positive outcomes, the study aims to (i) quantify key determinants, (ii) characterize spatial differentials across divisions, and (iii) identify an empirically appropriate prognostic model for the mortality outcome distribution.

MATERIALS AND METHODS
Study design and setting
A cross-sectional survey was conducted across five Lagos State divisions: Ikorodu, Badagry, Ikeja/Mainland, Lagos Island, and Epe in May 2023

Sampling Procedure
A stratified sampling design was adopted to ensure adequate representation of respondents across the major administrative divisions of Lagos State, Nigeria. Lagos State is traditionally

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divided into five geographical and administrative divisions: Ikorodu, Badagry, Ikeja (Mainland), Lagos Island, and Epe. These divisions served as the primary strata in the study because they represent distinct demographic and socio-economic environments within the state.
The sample size was determined using the Cochran formula for estimating proportions in large populations, expressed as:
$n = \frac{z^2 p(1-p)}{\varepsilon^2}$

where
n is the required sample size,
Z is the standard normal deviate corresponding to a 95% confidence level (1.96),
p is the assumed population proportion (0.5 in the absence of reliable community-level estimates), and
ε is the desired margin of error (0.04). Substituting these values yielded a minimum sample size of approximately 600 respondents. The total sample was proportionally allocated across the five divisions to ensure balanced representation. Within each stratum, selected communities were identified, and eligible women of reproductive age (15–49 years) who had experienced at least one live birth were surveyed using structured questionnaires. Respondents within communities were selected through systematic household visits and voluntary participation.
A total of 600 questionnaires were administered across the five strata. After data screening and the removal of incomplete responses, 476 valid questionnaires were retained for the final analysis. This sampling design ensured broad geographical coverage and improved the reliability of estimates of under-five mortality across Lagos State (see Appendix I). This approach ensured that information on child survival histories could be reliably obtained. The field researchers visited homes where women are within the age bracket (15 - 49) years, and the women filled out the questionnaires. For women (uneducated in English) who could not complete the questionnaires, the field researchers interviewed them and completed the questionnaires for them. The geographical map showing the 5 divisions in Lagos State is depicted in Figure 1.

Exclusion Criteria: The study focused on women of reproductive age (15–49 years) who had experienced at least one live birth. Therefore, the following groups were excluded from the study:

- Women who had never given birth, since the study required information on under-five child survival.
- Women outside the reproductive age range (below 15 years or above 49 years) at the time of the survey.
- Women who were not permanent residents of the selected communities were excluded in order to ensure that responses reflected the socio-demographic and environmental conditions of the study areas.
- Respondents who declined consent or were unavailable during the survey period.

Incomplete or improperly filled questionnaires could not provide reliable information for analysis. Following the application of these criteria and subsequent data screening, 476 valid responses were retained for the final analysis.

Figure 1. Map of Lagos State

Source: Lagos state government 2011

Data collection
-Of the 600 questionnaires administered, 476 were analyzed and used, giving a response rate of 79%. Data were entered into Excel and analyzed in SPSS 23.0 and Python.

Outcome variables
Two related outcomes were defined:

1. Binary under-five mortality experience (any death):

$$Y_i^{(B)} = \begin{cases} 1, \text{if respondent } i \text{ reported } \geq 1 \text{ under} - 5 \text{ death} \\ 0, \text{otherwise} \end{cases}$$

2. Count/severity outcome (number of under-five deaths):

$$Y_i^{(C)} \in \{0,1,2,3,4,5\}$$

representing the number of under-five deaths reported by respondent i.

Explanatory variables
Covariates were selected based on prior evidence (Aigbe & Zannu, 2012; Adekanmbi, 2015) and questionnaire availability:

- Mother's age (X_1)
- Marital status (X_2)
- Lagos division (X_3)
- Religion (X_4)
- Maternal education (X_5)

Prognostic modeling strategy
Logistic regression (binary outcome)
To model the probability of any reported under-five death:

$$\Pr(Y_i^{(B)} = 1) = \pi_i \quad (1)$$
$$\log\left(\frac{\pi_i}{1-\pi_i}\right) = \beta_0 + \sum_{j=i}^{5} \beta_j X_{ji} \quad (2)$$

Linear regression (baseline for severity outcome)
As a baseline approximation for the count-severity outcome:
$$Y_i^{(c)} = \beta_0 + \sum_{j=i}^{5} \beta_j X_{ji} + \varepsilon_i \qquad \varepsilon_i \sim N(0,\sigma 2). \quad (3)$$
This model is included for comparison but may be inadequate if the variance is non-constant and the outcome is skewed.

Gamma regression (severity outcome; distribution-aware model)
To accommodate skewness and heteroscedasticity in the severity outcome, a Gamma GLM was fitted with a log link:
$$Y_i^{(c)} \sim \text{Gamma}(\mu_i, \phi), \ \log(\mu_i) = \beta_0 + \sum_{j=i}^{5} \beta_j X_{ji} \quad (4)$$
(For zero counts, a small constant can be added, or the Gamma model can be applied to positive counts only; the implementation

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used in this study followed the software specification used for the reported tables. The Gamma regression model uses a logarithmic link function, making it appropriate for the positively skewed distribution of mortality rates. The model assumes the following form:

$$log(U5MR) = \beta_0 + \beta_1(SES) + \beta_2(ME) + \beta_3(HA) + \beta_4(NS) + \beta_5(S) + \beta_6(IC) \quad (5)$$

Model Selection and Evaluation

Model performance was assessed using standard diagnostic measures, including residual analysis and goodness-of-fit statistics. Residual plots were examined to assess the linearity assumption and identify potential model misspecification. The final model was selected based on its ability to adequately capture the relationship between under-five mortality and the explanatory variables while satisfying distributional assumptions.

In this study, Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) were employed as the model selection criteria, and they are calculated as follows:

$$AIC = -2logL + 2(k + 1) \quad (6)$$

where $\log L$ is the log-likelihood of the model and $k + 1 = p$ is the number of parameters in the model. If the sample size n is small, such that $\frac{n}{p} < 40$, the AIC should be adjusted to:

$$AIC_C = nlogL + 2p + \frac{2p(p+1)}{n-p-1}, \quad (7)$$

where p represents the number of parameters. The adjusted AIC in this equation indicates that as $n \to \infty$, $\frac{2p(p+1)}{n-p-1} \to 0$. The other model selection criterion applied is the BIC, which is generally expressed as:

$$BIC = nlogL + nlog(n) + plog(n) \quad (8)$$

where p is the number of parameters in the model and n is the sample size, the model with the lowest AIC and BIC values is considered the most appropriate model (Schwarz, 1978).

RESULTS AND DISCUSSION

Descriptive statistics and exploratory analysis

The age distribution of respondents is presented in Table 1. Of the 476 women surveyed, 59 (12.4%) were younger than 20 years, 180 (37.8%) were between 20 and 30 years, and 237 (49.8%) were older than 30 years. Thus, nearly half of the respondents were above 30 years of age. The mean age of respondents was 31.4 ± 8.6 years (range: 16–49 years). The distribution indicates that the majority of participants were within the economically and reproductively active age groups, which is appropriate for examining maternal and child health outcomes such as under-five mortality. The under-five mortality counts exhibited concentration at low values (including zeros) and evidence of non-normality. Exploratory plots suggested systematic relationships between mortality and both community division and maternal factors. Descriptively, Ikorodu, Badagry, and Epe recorded higher proportions of women reporting at least one under-five death than Lagos Island and Ikeja/Mainland. Let Y be a random variable signifying the number of under-5 mortality. The expected number of under-5 deaths of a mother is given by

$$E(y) = \frac{\sum_i f_i y_i}{\sum_i f_i}, \forall i \quad (9)$$

where f is the frequency of occurrence. The expected number of under-5 mortality to a mother in Lagos communities is

$$E(Y) = \frac{\Sigma i\, fiyi}{\Sigma i\, fi} = E(y) = \frac{160\times0+200\times1+67\times2+32\times3+9\times4+8\times5}{160+200+67+32+9+8} = \frac{506}{476} = 1.06$$

suggesting that communities with mean mortality counts above 1.06 may be prioritized as higher-burden settings under the study's definition.

Descriptive Characteristics of Respondents

Table 1 presents the socio-demographic characteristics of the 476 women included in the analysis. Nearly half of the respondents (49.8%) were aged 30 or older, while 37.8% were aged 20–30 years and 12.4% were younger than 20 years. The majority were married (66.2%), with 21.0% divorced and 12.8% single.

Table 1: Socio-demographic characteristics of the respondents (n=476)

Variable	Frequency	Percent (%)
Age of Respondents		
< 20 years	59	12.4
20–30 years	180	37.8
> 30 years	237	49.8
Marital Status		
Single	61	12.8
Married	315	66.2
Divorced	100	21.0
Division of Residence		
Ikorodu	98	20.6
Badagry	94	19.7
Ikeja (Mainland)	97	20.4
Lagos Island	97	20.4
Epe	90	18.9
Religion		
Christianity	268	56.3
Islam	152	31.9
Traditional/Other	56	11.8
Education Level		
No formal education	59	12.4
Primary education	144	30.3
Secondary education	150	31.5
Tertiary education	123	25.8

Respondents were fairly evenly distributed across the five Lagos divisions: Ikorodu (20.6%), Badagry (19.7%), Ikeja/Mainland (20.4%), Lagos Island (20.4%), and Epe (18.9%). Christianity was the dominant religion (56.3%), followed by Islam (31.9%), while 11.8% practiced other religions. In terms of educational attainment, 31.5% completed secondary education, 25.8% attained tertiary education, 30.3% had only primary education, and 12.4% had no formal education. This distribution reflects substantial educational heterogeneity among mothers, which is relevant for understanding child survival differentials.

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Summary Statistics of Study Variables
Table 2 summarizes the dependent and independent variables used in the regression analysis. The mean under-five mortality rate (U5MR) was 42.7 deaths per 1,000 live births, with a relatively large standard deviation (15.6), indicating considerable variability across communities. The mortality rate ranged from 15.2 to 78.3 per 1,000 live births.

Table 2. Summary statistics for dependent and independent variables

Variable	Mean	Standard Deviation	Range
Under-five mortality rate (per 1000 live births)	42.7	15.6	15.2 – 78.3
Socioeconomic status index	0.54	0.21	0.12 – 0.91
Maternal education (years)	7.8	4.3	0 – 16
Healthcare access index	0.67	0.18	0.25 – 0.95
Nutritional status (weight-for-age z-score)	-1.12	0.89	-3.45 – 1.21
Sanitation index	0.72	0.15	0.34 – 0.96
Immunization coverage (%)	82.5	11.4	45.0 – 98.0

The socioeconomic status index had a mean of 0.54, suggesting moderate economic conditions among respondents. Maternal education averaged 7.8 years, reflecting generally low schooling levels. Healthcare access and sanitation indices had mean values of 0.67 and 0.72, respectively, while immunization coverage was relatively high (82.5%) but still varied widely across communities.
The observed dispersion among these variables justifies the use of multivariable regression models to explain heterogeneity in under-five mortality outcomes.
The histogram in Figure 2 below depicts the distribution of the Under-5 Mortality Rate (U5MR) per 1,000 live births. The distribution is multi-modal, with distinct peaks observed at specific intervals, particularly around 35 and 50 U5MR. These multiple peaks suggest that the U5MR data may originate from various sub-populations or communities within the larger dataset. The central point of this distribution is approximately 42.7 per 1,000 live births, where the highest frequency is recorded. Another significant cluster is seen around 50 per 1,000 live births. The data range spans from about 25 to 55 U5MR, reflecting some variability in under-5 mortality rates across different observations or communities. While the frequencies are fairly evenly distributed across the different ranges, lower frequencies are noticeable in the 30–35 and 45–50 U5MR intervals. The presence of multiple peaks suggests that the data likely represent diverse communities with varying levels of healthcare access, socioeconomic status, or other factors influencing mortality rates. This range indicates that certain communities experience significantly higher mortality rates than others, potentially due to differences in healthcare infrastructure, maternal education, sanitation, or other socioeconomic factors.

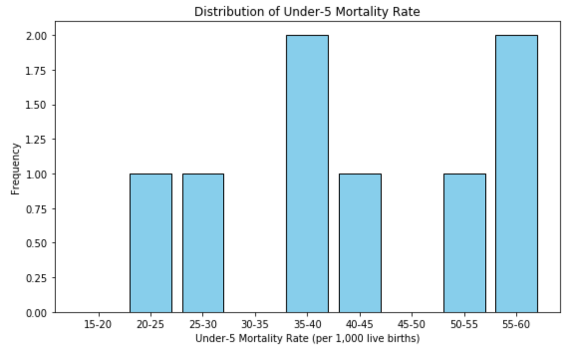

Figure 2. Distribution of under 5 Mortality

Distribution of Under-Five Mortality Across Lagos Divisions
Table 3 presents the expected number of under-five deaths per mother across Lagos divisions. The overall expected number of under-five deaths per mother was 1.06, serving as a benchmark for identifying high-burden communities.

Table 3. Expected Number of under-5 Mortality across Lagos communities

Lagos division	0	1	2	3	4	5	Total mothers	Total under-5 deaths	Mean
Ikorodu	4	57	22	10	2	3	98	154	1.57
Badagry	12	50	17	10	3	2	94	136	1.45
Ikeja	59	22	15	1	0	0	97	55	0.57
Lagos Island	64	28	2	3	0	0	97	41	0.42
Epe	21	43	11	8	4	3	90	120	1.33
Total	**160**	**200**	**67**	**32**	**9**	**8**	**476**	**506**	**1.06**

Ikorodu recorded the highest mean number of under-five deaths (1.57), followed by Badagry (1.45) and Epe (1.33). These values exceed the overall mean, indicating elevated mortality burden. Ikeja (0.57) and Lagos Island (0.42) recorded substantially lower mortality levels.
Table 4 further distinguishes women who had never experienced an under-five death from those who had lost at least one child. Ikorodu exhibited the highest proportion of women reporting under-five deaths (94 out of 98), followed by Badagry (82 out of 94) and Epe (69 out of 90). Lagos Island and Ikeja had relatively lower mortality exposure.

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Table 4. Number of under 5 Death or Alive

		Death		Total
		Alive	**Death**	
Lagos division	Ikorodu	**4**	**94**	**98**
	Bada gry	**12**	**82**	**94**
	Ikeja	**59**	**38**	**97**
	Lagos Island	**64**	**33**	**97**
	Epe	**21**	**69**	**90**
Total		**160**	**316**	**476**

These patterns reveal pronounced spatial inequality in child survival within Lagos State, despite its urbanized status.

Gamma Regression Results for Under-Five Mortality Severity
Table 5 presents the Gamma regression estimates modeling the expected number of under-five deaths per mother. The Gamma model was chosen because of the positively skewed nature of the mortality counts and evidence of heteroscedasticity.

Table 5. Gamma Regression model result

Predictor	**Coefficient**	**Standard Error**	**z-value**	**p-value**
Intercept	2.456	0.312	7.87	<0.001
Socioeconomic Status	-1.134	0.258	-4.39	<0.001
Maternal Education	-0.065	0.021	-3.10	0.002
Healthcare Access	-0.852	0.297	-2.87	0.004
Nutritional Status	0.034	0.011	3.09	0.002
Sanitation	-0.674	0.244	-2.76	0.006
Immunization Coverage	-0.032	0.012	-2.67	0.008

All predictors were statistically significant at the 1% and 5% level.
Socioeconomic Status (SES) had a strong negative effect ($\beta = -1.134$, $p < 0.001$), indicating that improved household economic conditions substantially reduce under-five mortality.
Maternal Education was negatively associated with mortality ($\beta = -0.065$, $p = 0.002$), confirming that higher educational attainment improves child survival. Healthcare Access significantly reduced under-five mortality ($\beta = -0.852$, $p = 0.004$), reflecting the importance of antenatal care, skilled delivery, and child health services. Sanitation showed a protective effect ($\beta = -0.674$, $p = 0.006$), underscoring the role of clean water and hygiene in preventing childhood illnesses. Interestingly, the study found that religion and maternal education were not statistically significant predictors of under-five mortality in the full model. While education is often considered a key determinant of child health outcomes, the lack of statistical significance in this study may reflect contextual factors specific to the study population. For instance, the relatively high level of basic education in urban areas such as Lagos may reduce variation in educational attainment among respondents, thereby limiting its explanatory power in the model. Additionally, other socioeconomic factors such as income, healthcare access, and living conditions may mediate the relationship between education and child survival outcomes.
Immunization Coverage was also protective ($\beta = -0.032$, $p = 0.008$). Nutritional Status exhibited a positive association with mortality ($\beta = 0.034$, $p = 0.002$), implying that higher prevalence of underweight children increases mortality risk.
This study examined the socio-demographic determinants of under-five mortality using a Gamma regression modeling framework among mothers in selected divisions of Lagos State. The findings revealed that marital status and Lagos division were statistically significant predictors of under-five mortality, while age showed marginal significance. In contrast, religion and educational level were not significant predictors in the full model specification.
The results indicate that marital status plays an important role in child survival outcomes. The negative coefficient observed for marital status suggests that mothers who are married are associated with lower under-five mortality counts compared with their unmarried counterparts. This finding is consistent with previous studies that have reported that children born to married women tend to have better survival outcomes due to greater economic stability, emotional support, and shared parental responsibilities. Studies conducted in sub-Saharan Africa have similarly found that children of unmarried mothers often experience higher mortality risks due to socioeconomic vulnerabilities, limited access to healthcare resources, and reduced household support systems. Married mothers are more likely to benefit from shared decision-making, better financial resources, and improved caregiving capacity, which may positively influence child health outcomes. From a methodological perspective, the study demonstrates the value of distribution-aware prognostic modeling for child mortality research. By accommodating skewness and heteroscedasticity in mortality counts, the Gamma regression model provides more reliable inference than conventional linear approaches.
These findings indicate that urbanization alone does not eliminate child survival inequalities and that community-specific vulnerabilities persist within metropolitan settings.

Interpretation (Gamma log-link)
Because the Gamma model uses a log link, exponentiated coefficients represent multiplicative effects. For example: A one-unit increase in SES reduces the expected number of under-five deaths by approximately 68% ($e{-}1.134 \approx 0.32$). Each additional year of maternal education reduces expected under-five deaths by about 6.3%. Improved healthcare access lowers expected mortality by nearly 57%. These effects are substantial and policy-relevant.

Model Adequacy and Implications
The Gamma regression model outperformed linear regression in capturing skewness and non-constant variance in under-five mortality counts, validating the use of distribution-aware prognostic modeling. The strong and consistent effects of socioeconomic status, maternal education, healthcare access, sanitation, nutrition, and immunization reinforce the multifactorial nature of child survival. The persistence of spatial differentials across Lagos divisions suggests that urbanization alone does not guarantee equitable health outcomes, and targeted interventions remain necessary.

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Prognostic Regression Analysis Estimation

In this study, the response variables (Y) are (i) number of children born by a woman who died before age 5. (ii) response of a woman to whether she has lost a child (below age 5), with response 0, if she has not lost a child, and 1 if she has lost at least a child. The probability distribution $P(Y_i = 1) = \pi_i$ or $P(Y_i = 0) = 1 - \pi_i$, where response variable (Y) denotes death or alive. The independent variables or covariates are age of mother (X_1), marital status of mother (X_2), division in Lagos State where mother lives (X_3), mother's religion (X_4) and mother's education (X_5). The term mother used here refers to our respondents who have given birth to at least one child.

There are basically two different models. One is a binary response and will be modelled using binary logistic regression. The other is a count response and will be modelled by linear regression, and gamma regression. The count response is a subset of the continuous response. If the sample size is large enough, then it can be approximated by a continuous distribution, which in most cases Gaussian, the basis for the linear regression. However, it can be gamma, weibull or any other continuous distribution.

• **Model A: Binary Response Variable**
- Use all the covariates (binary logistic regression)
- Drop a covariates that is not significant (binary logistic regression)

• **Model B: Count Response Variable**
- Use all the covariates (linear model)
- Drop a covariates that is not significant (linear model)
- Use all the covariates (linear model)
- Drop a covariates that is not significant (linear model)

Models 1 and 2 in A are competing models. Models 3, 4, 5 and 6 are competing models. Models in A are not competing with models in B. We are not only interested if a woman has lost a child or not, we are also interested in the number of children a woman lost. This will help to measure under 5 mortalities.

Fitting Multivariable Gamma Regression Models

Table 6. Gamma Regression Estimates of 5 Covariates

Variables	Estimate	Std. Error	Z value	P-value
Intercept	0.871717	0.114678	7.601	0.00000
Age	-0.047057	0.027324	-1.722	0.08569
Marital Status	-0.072553	0.027794	-2.610	0.00933
Lagos Division	-0.030271	0.012835	-2.359	0.01875
Religion	0.013137	0.025843	0.508	0.61146
Education	-0.002739	0.017322	-0.158	0.87444

Table 6 presents the Gamma regression estimates for the full model including five covariates. The results show that marital status (β = −0.0726, p = 0.0093) and Lagos division (β = −0.0303, p = 0.0188) are statistically significant predictors of under-5 mortality counts at the 5% significance level. This suggests that variations in marital status and geographical division are associated with differences in the mortality outcome.

The coefficient for age (β = −0.0471) is negative, indicating that increases in maternal age are associated with a decrease in the expected mortality count under the Gamma regression framework. However, the p-value (0.0857) exceeds the conventional 5% significance threshold, implying that age is not statistically significant at the 5% level, though it is marginally significant at the 10% level. This suggests that age may still contribute to explaining variability in the response variable and may warrant inclusion in a reduced model for theoretical or model-fit considerations.

In contrast, religion (p = 0.6115) and education (p = 0.8744) are not statistically significant predictors in the full specification, indicating that their effects on mortality counts are not supported by the data in this model.

Consequently, the reduced Gamma model (Table 7) retained age, marital status, and Lagos division, as these variables provided improved model performance based on information criteria while maintaining meaningful explanatory contributions.

Model 5 regression parameters estimated in Table 6 can be expressed as

$$\hat{\mu}_i = \frac{1}{0.871717 - 0.047057x_{1i} - 0.072553x_{2i} - 0.030271x_{3i} + 0.013137x_{4i} - 0.002739x_{5i}} \quad (10)$$

Table 7 shows that some of the covariates are not significant at 5% level. Religion and education are not significant, even at 10% level. So, there is a need to develop model 6 by dropping religion and education.

Table 7. Gamma Regression Estimates of 3 Covariates

	Estimate	Std. Error	Z value	P-value
Intercept	0.86756	0.10436	8.313	0.00000
Age	-0.04535	0.02709	-1.674	0.0949
Marital Status	-0.06680	0.02543	-2.627	0.0089
Lagos Division	-0.02875	0.01246	-2.306	0.0215

Reduced Gamma model (selected):
log(μi)=β0+β1(Age)+β2(Marital Status)+β3(Division), with parameter estimates corresponding to Table 7.

Model 6 regression parameters estimated in Table 7 can be expressed as

$$\hat{\mu}_i = \frac{1}{0.86756 - 0.04535x_{1i} - 0.06680x_{2i} - 0.02875x_{3i}} \quad (11)$$

Interpretation (log-link): exponentiated coefficients represent multiplicative changes in expected mortality count associated with one-unit changes in predictors (or relative to reference categories).

Model Selection Criteria

Table 8. Model Selection Criteria for Binary Response

Models	-logL	AIC	BIC
Binary Logistic Regression			
Model 1 (5 covariates)	237.6006	487.2000	512.1937
Model 2 (4 covariates)	238.8635	487.7300	508.5541

For the binary outcome, Model 1 (5 covariates) outperformed Model 2 (4 covariates) by AIC/BIC, indicating that retaining the full set improved the binary prognostic fit under the study's criterion

(Table 8).

Table 9. Model Selection Criteria for Count Response

Models	-logL	AIC	BIC
Multiple Linear Regression			
Model 3 (5 covariates)	673.8634	1361.7270	1390.8850
Model 4 (4 covariates)	674.8924	1361.7850	1386.7770
Multiple Gamma Regression			
Model 5 (5 covariates)	604.3016	1222.6000	1251.7610
Model 6 (3 covariates)	604.4812	1219.0000	1239.7900

For the severity outcome, the Gamma family achieved lower AIC/BIC than the linear model family. Within Gamma models, the reduced model (Model 6) yielded the best AIC/BIC (Table 9), supporting the conclusion that distribution-aware modeling improves fit for the mortality-count severity target. The findings underscore the importance of targeted interventions in these areas to reduce under-5 mortality rates.

Key empirical implications

Three robust patterns emerge across analyses:

Spatial differentials: Under-five mortality burden is higher in Ikorodu, Badagry, and Epe relative to Lagos Island and Ikeja/Mainland. Another important finding of this study is the significant effect of geographical division (Lagos division) on under-five mortality. The results suggest that mortality outcomes vary significantly across divisions within Lagos State. This spatial disparity may reflect differences in access to healthcare facilities, quality of maternal and child health services, socioeconomic conditions, environmental sanitation, and infrastructure development across different areas. Previous studies have documented substantial geographic inequalities in child mortality within urban settings, where communities with limited healthcare infrastructure or poorer living conditions often experience higher mortality rates. In densely populated urban environments such as Lagos, variations in housing conditions, access to safe water, and healthcare accessibility may contribute to these differences in child survival outcomes.

Maternal characteristics: Marital status and age show associations with mortality burden in the severity model, with division remaining consistently important. Maternal age was found to have a negative association with under-five mortality, although it was only marginally significant in the full model at the 10% level. The negative relationship suggests that increases in maternal age may be associated with a reduction in mortality risk among children. This finding aligns with demographic and epidemiological literature suggesting that older mothers may possess greater parenting experience, improved health-seeking behaviour, and better knowledge of childcare practices compared with younger mothers. Younger mothers, particularly adolescents, may face biological risks, limited access to healthcare services, and insufficient knowledge of optimal child care practices, which could contribute to higher mortality risks among their children.

Modeling implication: Gamma regression provides a better empirical description for the severity outcome than Gaussian regression in this dataset, consistent with non-normality and heteroscedasticity concerns. The reduced Gamma regression model retained age, marital status, and Lagos division as key explanatory variables and showed improved model performance based on information criteria. This suggests that these variables capture the most important sources of variation in the mortality outcome within the study population.

Health Implications for the study

The findings of this study have several important public health implications. First, the significant influence of marital status highlights the need for targeted support programs for single mothers and vulnerable households. Public health interventions aimed at improving maternal and child health should consider providing additional social and healthcare support for unmarried mothers, including improved access to antenatal care, child health education, and economic empowerment programs.

Second, the observed geographical disparities in under-five mortality across Lagos divisions underscore the importance of addressing inequalities in healthcare access and service delivery. Policymakers should prioritize the equitable distribution of maternal and child health services, particularly in divisions that may experience higher mortality burdens. Strengthening primary healthcare systems, improving immunization coverage, and enhancing community health outreach programs could significantly reduce child mortality rates in underserved areas.

Third, the marginal significance of maternal age suggests the need for strengthened reproductive health education and maternal support programs, especially for younger mothers. Interventions such as adolescent reproductive health education, family planning services, and maternal health awareness campaigns could help reduce risks associated with early childbearing and improve child survival outcomes.

Conclusion and Recommendations

The analysis revealed substantial heterogeneity in under-five mortality both across communities and across maternal and household characteristics.

Empirically, the findings show that under-five mortality in Lagos State remains strongly shaped by socioeconomic and structural factors. The Gamma regression model—identified as the best-fitting specification—demonstrated that improvements in household socioeconomic status, maternal education, healthcare access, sanitation, and immunization coverage are associated with substantial reductions in the expected number of under-five deaths. Conversely, poor nutritional status significantly increased mortality risk.

Marked spatial disparities were observed across Lagos divisions, with Ikorodu, Badagry, and Epe consistently exhibiting higher under-five mortality burdens than Ikeja and Lagos Island. Policy recommendations include targeted interventions in high-burden communities, strengthening primary healthcare delivery, promoting maternal education, improving nutrition and sanitation, and ensuring effective implementation of free child healthcare policies.

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Overall, reducing under-five mortality in Lagos State requires a coordinated, multi-sectoral approach guided by robust prognostic evidence.

Conflict of interest
On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Appendix I
QUESTIONNAIRE ON INFANT MORTALITY IN THE DIVISIONS OF LAGOS STATE

(QOIM)

The aim of this questionnaire is to elicit information on the causes of infant mortality in Lagos state.

Please complete the questionnaire below as accurate as possible. All information given will be treated as confidential and used only for research purposes. The success of this study depends on your cooperation and so you are implored to respond to the items appropriately.

SECTION A: PERSONAL INFORMATION

1. SEX: MALE ( ) FEMALE ( )

2. PRESENT AGE: BELOW 20 YEARS ( ) 20-30 ( ) ABOVE 30 YEARS ( )

3. STATUS: MARRIED ( ) DIVORCED ( ) SINGLE ( )

4. DIVISION OF LAGOS OF RESPONDENT: IKORODU ( ) BADAGRY ( ) IKEJA ( ) LAGOS ISLAND ( ) EPE ( )

5. RELIGION: CHRISTIANITY ( ) ISLAM ( ) OTHERS ( )

6. EDUCATION STATUS: NO SCHOOL ( ) PRIMARY ( ) SECONDARY ( ) TERTIARY ( )

7. NUMBER OF CHILDREN IN HOUSEHOLD: 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) More than 6 ( )