Transactions of the Nigerian Association of Mathematical Physics
Volume 10, (*July and November, 2019*), pp141 – 148

STRUCTURED ADDITIVE REGRESSION MODEL USING MULTINOMIAL RESPONSE AND ITS APPLICATION TO CHOICE PLACE OF DELIVERY

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Abstract

Access to quality healthcare during childbirth is a crucial factor for taming maternal and child mortality and morbidity. Increasing this access in developing countries depends on understanding the factors influencing maternal healthcare decision at a geographical location. This study examined the additive regression model to capture the linear effects, the non-linear effects and the spatial effects in a unified framework. The spatial covariate was assumed to follow Markov random field prior, second order random walk prior for the non-linear effects, while a diffuse prior was assumed for the linear effects. The secondary data obtained from demography and health surveys in the West Africa country (Guinea) was used to model women choice of place of delivery and associated factors. The result shows that education, wealth and women dwelling in an urban area were positively associated with delivery taking place in a health facility center. It was also discussed that the religion played a significant role. The women who practiced Islamic religion had a negative significant likelihood of delivering in a health facility center. The likelihood of delivery taking place in a health facility center increases as the mother increase in age, while the likelihood decreases as the number of children given birth to by the woman increases.

Keywords: Guinea, Multinomial response, Place of delivery, Structured additive regression model, Spatial covariate, West Africa.

1. INTRODUCTION

Access to quality healthcare during pregnancy and, in particular, during delivery is a crucial factor in explaining the huge disparity in maternal and perinatal mortality and morbidity between developing and the industrialized world. Approximately half of the world's maternal deaths occur in Sub-Saharan Africa, mostly as result of complications including hemorrhage, eclampsia, obstructed labour, and infections [1]. Many of these would be largely prevented with health facility delivery assisted by Skilled Birth Attendants (SBAs). Yet, a large percentage of women in West Africa do not deliver in health facilities.

Women have varying experiences and perceptions of choice of place delivery. Most women had or perceived they had no choice, though some felt they had a genuine choice. When comparing different places of birth, women based their decision primarily on their perceptions of safety [2]. It is observed that the sociocultural, economics and geographical circumstances and quality of health care services among others are responsible for women choice of place of delivery, to better understand how to address the delay in the use of skilled delivery; numerous studies have examined determinants of whether a woman delivers in a health facility or at home.

A study carried out in [3] shows that Educational status of women was found to be the most significant factor influencing place of delivery. Women with secondary or higher level of education are more likely to utilize health facility delivery care services.

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In [4], a study on spatial analysis of choice of place of delivery in Nigeria using structured additive regression model. The choice of place delivery that was considered as a multi-categorical response and a multinomial logistic regression model was used to evaluate the spatial variations in choosing a particular place to deliver against home delivery. It was found out that the likelihood of institutional delivery was significantly lower for women residing in Bayelsa and the majority of the states in northern Nigeria. Also as women advance in age, they have more likelihood of having institutional deliveries. Other contributing factors that favour institutional deliveries include use of antenatal care services, urban dwelling, mass media and parity.

Also, in [5], it was found out that more than ninety percent of the entire pregnant woman in Tanzania attended antenatal care at least once, yet less than five in ten received skilled delivery care at available health centre. The study framework presented three categories of factors related with health facility delivery: physical and economic accessibility, sociocultural and perceived needs and benefits of facility delivery.

Examining associations of birth location preferences on pregnant women's experiences is important to understand delays in care seeking in the event of complications.

Majority of previous studies on maternal healthcare utilization have considered and modeled all determinants parametrically and also neglected the possibility of any geographical variation. Such assumption of linear predictor for assessing the effects of metrical covariates on the response variable is too restrictive and rigid in realistically complex situations. In this study, a unified multinomial modeling framework that enables investigations of the association between the choices of place of delivery, individual and household characteristics as well as region specific effects is adopted.

2.0 MATERIALS AND METHODS

The data used in this study are secondary data sourced from the data base of the Demographic and Health Surveys (DHS) program carried out on women choice of delivery in Guinea. The approval to use this data was obtained from Measure DHS.

The study considered three categories of the response variable:

i. Public sector
ii. Private sector
iii. Home or other place of delivery

The study suggests that factors associated with choice of place of delivery are

i. Educational level
ii. Wealth index
iii. Religion
iv. Region
v. Mother's age
vi. Numbers of previous children
vii. Area

2.1 DATA ANALYSIS

MULTINOMIAL RESPONSE

The response variable is multinomial, hence for a multinomial responses, the usual choice is the multinomial logit model, where the probability of category r

$$P(Y = r) = \pi^r(\eta^1 \dots \eta^q) = \frac{\exp(\eta^r)}{1 + \sum exp(\eta^s)} \quad (1)$$

with r =1, ..., S-1 and $\eta^r = u^0\gamma^r$ where the $u^0\gamma^r$ is the linear predictor, depending on covariates u and category-specific vector of regression coefficients γ^r

The logit models for multinomial responses pair each response category to a reference category and the choice is arbitrary. If the last category is the reference, then the reference-category logits are

$$\ln\left[\frac{p(Y=1/x)}{p(Y=3/x)}\right] = \beta_{10} + \beta_{11}x_1 + \dots + \beta_{1p}x_p = \beta_1' x \quad (2)$$

$$\ln\left[\frac{p(Y=2/x)}{p(Y=3/x)}\right] = \beta_{20} + \beta_{21}x_1 + \ldots + \beta_{2p}x_p = \beta_2' x \quad (3)$$

Under this model, the response probabilities are

$$P(Y = 1/x) = \frac{e^{\beta_1' x}}{1+\beta_1' x + \beta_2' x} \quad (4)$$

$$P(Y = 2/x) = \frac{e^{\beta_1' x}}{1+\beta_1' x + \beta_2' x} \quad (5)$$

$$P(Y = 3/x) = \frac{e^{\beta_1' x}}{1+\beta_1' x + \beta_2' x} \quad (6)$$

With unknown parameters $\beta = (\beta_1', \beta_2')$ Now, we recode the outcome variables as the following $Y_1 = 1, Y_2 = 0, Y_3 = -1 \; for \; Y = 1, Y_1 = 0, Y_2 = 1, Y_3 = -1 \; for \; Y = 2$. With note that no matter what value y takes on the sum of these variables is $\sum_{i=1}^{k} p_i = 1$

The conditional likelihood function given the covariates for sample of n independent observation is

$$L(\beta) = \prod[\left(\frac{e^{\beta_1' x}}{1+\beta_1' x + \beta_2' x}\right) y_{1i} \left(\frac{e^{\beta_2' x}}{1+\beta_1' x + \beta_2' x}\right) y_{2i} \left(\frac{1}{1+\beta_1' x + \beta_2' x}\right) y_{3i} \quad (7)$$

Taking log on both sides we have,

$$L(\beta) = \sum [y_{1i}(\beta_1' x - \ln(1 + \beta_1' x + \beta_2' x)) + y_{2i}(\beta_2' x - \ln(1 + \beta_1' x + \beta_2' x)) + y_{3i}(\ln(1 + \beta_1' x + \beta_2' x))] \quad (8)$$

2.2 STRUCTURED ADDITIVE REGRESSION

Structured additive regression models is considered in this work because it extend the common linear predictors to more general semi parametric additive predictors, because it offered a flexible extension to standard regression models by enabling simultaneous modelling of possible nonlinear effects of continuous covariates, spatial correlation and heterogeneity, while estimating usual fixed effects of categorical and continuous observed variables.. We consider model of increasing complexity of multinomial responses if all effects are assumed to be category-specific

Then, the model takes the form

$$\eta^r = f_1^r(x_1) + \ldots + f_n^r(x_n) + f_{spat}^r(s_i) + u'\gamma^r \quad (9)$$

Where $f_1^r \ldots f_n^r$ are unknown smooth functions of the continuous covariates of $x_1 \ldots x_n, u^1\gamma^r$ corresponds to the usual parametric linear part of the predictor which can be used to model each category r of the response and the f_{spat}^r also represents the possibly nonlinear spatial effects. The covariates are assumed to be independent of the category while effects are category specific. Since we adopt a Bayesian perspective, both fixed effects and random effects are random variables. They are distinguished by different priors, e.g., diffuse priors for fixed effects and Gaussian priors for independent and identically distributed random effects.

We express the vector of function evaluations $f_j = f_j(x_{1j}), \ldots, f_j(x_{nj})$ of an unknown function f_j as the matrix product of a design matrix x_j and a vector of unknown parameter β_j , i.e., $f_j = x_j\beta_j$

Similarly, prior for β_j can be brought into a general form as well.

The general form of the prior is given by

$$p\left(\frac{\beta_j}{\tau_2}\right) \propto \exp\left(\frac{-1}{2\tau^2}\beta_j' k_j \beta_j\right) \quad (10)$$

Where k_j is a penalty matrix that penalizes too abrupt jumps between neighboring parameters. In most cases k_j will be rank deficient and therefore the prior for β_j will be partially improper. The variance parameter τ_j^2 is the control tradeoff between flexibility and smoothness.

Estimation of regression parameters is based on full Bayesian inference via MCMC. A fully Bayesian interpretation of STAR models is obtained by specifying prior distributions for all unknown parameters.

2.3 PRIOR FOR FIXED EFFECTS

We assumed diffuse priors $p(y) \propto constant$ for the fixed effect parameters γ^r.

2.4 PRIOR FOR NON-LINEAR EFFECTS

A flexible and parsimonious possibility to model non-linear effects of metrical covariates are P-splines.
Basic assumption: f_j(x) = spline of degree *l* with equally spaced inner knots

$$t_1, \dots, t_r \; between \; x_{min} \; and \; x_{max} = \beta_{j1} B_{j1}(x) + \dots \beta_{j,} r + l + 1 B_j, r + l + 1(x) \qquad (11)$$

Where $B_{j1}, \dots, B_{j,r+l+1}$ is a B-spline basis.
The design matrix X_j consists of the basic functions evaluated at the observations, i.e. $X_{j(i,k)} = B_{jk}(x_i)$

2.5 SPATIAL COVARIATES

The values $x \in (1, \dots s \dots S)$ represent the location or site in geographical regions.
Each site is associated with one parameter, i.e. $f_j str(s) = \beta_j sstr$
A common choice are Markov random fields [6] for the structured effect, i.e.

$$\beta_{js}^{str} / \beta_{j,-s}^{str}, \tau_j^2 \sim N(\sum_{k \epsilon \partial_s} \frac{1}{N_s} \beta_{jk}^{str}, \frac{1}{N_s} \tau_j^s) \qquad (12)$$

where
∂_s denotes the sites, which are neighbors of sites and N_s are the numbers of neighbors

3.0 RESULTS, DISCUSSIONS AND CONCLUSION

3.1 EXPLORATORY DATA ANALYSIS

Table 1: Summary of individual covariates analyzed and percentage distributions of place of delivery by all women respondents based on data collected from DHS.

Place of delivery	Home/others	Private sector	Public sector	Number of women
Urban	50.95	42.98	6.07	3490
Rural	29.29	56.80	13.91	1854
No Education	51.22	42.74	6.02	2358
Primary	44.21	48.49	7.30	1794
Secondary	28.52	56.69	14.80	1108
Higher	4.76	55.95	39.29	84
Poor	51.95	44.34	3.71	3182
Middle	36.98	53.78	9.24	1125
Rich	24.30	51.78	23.29	1037
Islam	39.84	55.26	4.88	635
Christian	43.37	47.04	9.60	4522
Other	58.43	39.33	2.23	178

3.1 FIXED EFFECT RESULT

Table 2: Guinea: odd ratio (OR) and 95% (CI) for the fixed effects covariates

	Home against Private sector		Public against Private sector	
parameters	OR	95% CI	OR	95% CI
constants	0.551	(0.368,1.210)	1.931	(1.236,3.393)
level of education				
no education (ref)	1	1	1	1
primary	1.795	(1.373,2.340)*	0.538	(0.337,0.698)*
secondary	1.247	(0.945,1.613)	0.766	(0.461,0.995)*
higher degree	0.218	(0.109,0.427)*	1.770	(0.942,2.32)
wealth index poor (ref)	1	1	1	
middle	0.986	(0.876,1.093)	1.011	(0.906,1.139)
rich	0.751	(0.651,0.856)*	1.358	(1.165,1.539)*
religion others(ref)	1	1		
Islam	0.649	(0.537,0.776)*	1.538	(1.296,1.802)*
Christian	1.002	(0.873,1.124)	0.999	(0.851,1.130)
Area rural(ref)	1	1	1	1
urban	1.726	(1.501,2.073)*	1.478	(1.194,1.927)*

The result of the fixed effects presented in table 2 shows that comparing women with no education, those with primary level of education were 79.5% significantly more likely and 46% significantly less likely to deliver at home and public sector respectively against private sector. Women with secondary level of education were 24.7% more likely to deliver at home, but not significant, however 23% significantly less likely to deliver at a public sector against private sector. While women with higher degree level of education were 79% significantly less likely to deliver at home against private sector and 77% more likely to give birth at a public sector against private sector.

Comparing with women who belong to the poor quantile of wealth index, those who belong to the middle quantile were 4% less likely and 1% more likely to deliver at home and public sector respectively against private sector, however none of these is significant. But for women who belong to the rich quantile of wealth index, the odds of delivery taking place at home and public sector were 25% significantly higher and 36% significantly lower respectively.

Results also show that compared with respondents who practiced other religion, the odd of delivery taking place at home and public sector against private sector were 35% significantly lower and 54% significantly higher respectively for women who practiced Islamic religion. But for women practiced who Christianity religion, the result show that it has no significant effect on where they deliver.

Again women who dwelled in the urban area against rural area were 72.6% and 47.3% significantly more likely to deliver at home and public sector respectively against private sector.

3.2 NON-LINEAR EFFECTS

Results of the nonlinear effects of mother's age at birth and current number of children are shown in Figure. 1, 2, 3 and 4 respectively. Shown are the posterior modes and 95% CI.

Non-linear Effects

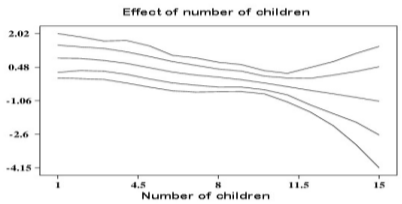

Figure 1: The posterior means and 95% CI of the non-linear effect of number of children on home against private place of delivery

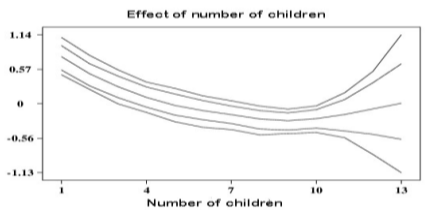

Figure 2: The posterior means and 95% CI of the non-linear effect of number of children on public against private place of delivery against private sector.

The non linear effects of mother's previous number of children are shown in figure 1 and 2 shown are the posterior means and 95% CI. The result shows that non-linear relationship exists between the response variable and number of children, assuming linear relationship would have led to spurious regression. The results show that as the number of children increase, the likelihood of delivery taking place at home against private sector decreases. The result also show that the odd reduced as the number of children increase to 8, then stabilize afterward for delivery to take place at public sector against private sector.

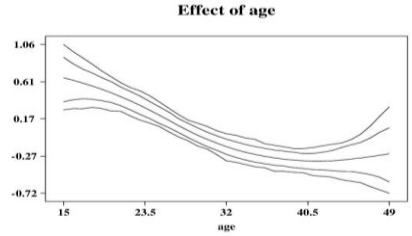

Figure 3: The posterior means and 95% CI of the non-linear effect of age on home against private place of delivery

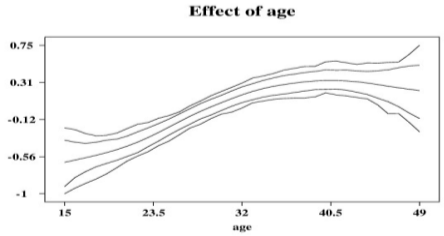

Figure 4: The posterior means and 95% CI of the non-linear effect of age on public against private place of delivery

Figure 3 and 4 shows the non-linear effects of mother's age on the response variable. The result show that the odds decreases with increase in the mother's age up to around age 40 before stabilizing, for delivery taking place at home against private sector. Findings also reveal that the odds of delivery taking place at public sector against private sector increase as the mothers age increase up to around age 35.

3.3 SPATIAL EFFECTS

Figure 5, 7 and 6, 8 shows the posterior mean and 95% CI respectively of the non-linear spatial effects on the response variable. From this, regions with white (black) colour were associated with significantly higher (lower) likelihood for a particular choice versus private sector, while the likelihood was not significant for the region with grey color.

Figure 5: Map of Guinea

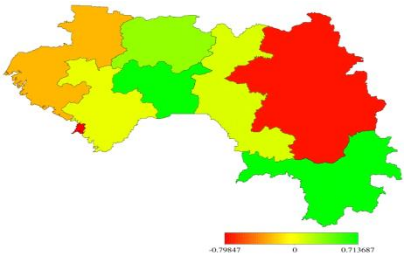

Figure 6: The posterior means of the non-linear spatial effect on home against private place of delivery

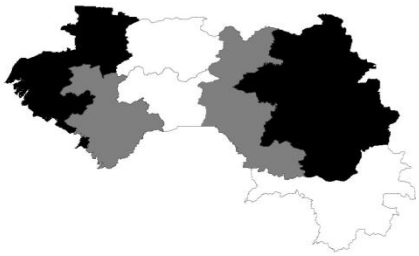

Figure 7: 95% CI of the non-linear spatial effect on home against private place of delivery

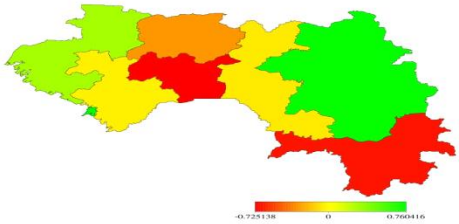

Figure 8: The posterior means of the non-linear spatial effect on public against private place of delivery

Figure 6 shows that women residing in Labe, Mamou and Nzerekore had a significantly higher likelihood of choosing to deliver at home, while those women residing in other regions had a lesser likelihood of delivering at home except Faranah and Kindia which had no significant effect.

Figure 9: 95% CI of the non-linear spatial effect on public against private place of delivery

Also, figure 8 shows that women residing in Labe, Mamou and Nzerekore were significantly less likely to choose to deliver at public sector, while women residing in other regions were significantly more likely to choose to deliver at public sector except Faranah and Kindia which had no significant effect.

3.4 DISCUSSIONS

Structured Additive Regression model was used to examine women choice of place of delivery in Guinea. Data was obtained from Demography and Health survey for one West African country (Guinea) to model women choice of place of delivery and factors associated with it from literature were considered.

The results shows that the variable that are significant on women delivery at home against private sectors were women with secondary and higher degree level of education, those who belong to the rich quartile of wealth index, those who practiced Islamic religion and those who lived in the urban area. For the delivery taking place at a public sector against private sector, the variables that make significant impact are women with secondary school level of education, those who belong to the middle and rich quartile of the wealth index, those who practiced Islam and Christian religion and those who live in the urban area. Figures 1 and 3 shows the trend of the non linear effect of number of children and mothers age respectively on delivery taking place at home against private sector, while Figures 2 and 4 shows the non linear effect of number of children and the age of the mother respectively on delivery taking place at public sector against private sector. Figures 6 and 8 shows the map of 95% CI and the mean of the spatial effect respectively on delivery taking place at home against private sector, while Figures 7 and 9 shows the map of 95% CI and the mean of the spatial effect respectively on delivery taking place at public sector against private sector. From this, region with white colour are associated with significantly higher likelihood for a particular choice versus private sector and region with black colour are associated with significantly lower likelihood for a particular choice versus private sector while, the likelihood was not significant for region shaded with grey color.

3.5 CONCLUSION

The results show that education, wealth and women dwelling in an urban area are positively associated with delivery taking place in a health facility center, the results also show that religion played a significant role whereby women who practiced Islamic religion had a lesser significant likelihood of delivery taking place in a health facility center. The results also show that the likelihood of delivery taking place in a health facility center increases as the mother increases in age, while the likelihood decreases as the number of children given birth to by the woman increases. Finally , the result indicate the existence of spatial effect, where some regions are positively associated with delivery taking place in health facility center, while some regions were negatively associated while some regions show no significant effect. Based on these findings, improving the utilization of health facility for delivery through educating women and health promotion has been recommended. This will help reduce the danger that often characterized home based, unsupervised delivery.

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