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Poverty Levels and Maternal Nutritional Status as Determinants of Weight at Birth: An Ordinal Logistic Regression Approach

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Abstract This paper explores the possible influence of household poverty levels and maternal nutritional status on child's weight at birth. The 2003 Nigeria Demographic Health Survey (NDHS) measures weight at birth on an ordinal scale. Therefore, modelling techniques that take cognizance of ordinal responses are suitable for this situation. Ordinal logistic regression technique was employed for all analyses. Quintiles of wealth index were used as a measure of assets owned by households while body mass index was used to assess maternal nutritional status. Other demographic characteristics such as mother's age at birth of the child, educational attainment, locality (urban/rural) and geo-political zones were controlled for in the models. The sample size for survey was 5138. Wealth index and maternal nutritional status were positively associated with child's weight at birth, while mother's educational attainment was not statistically significant. Significant and positive association of wealth index was evident with middle and richest when compared with those in the poorest category of wealth index. Mothers that were underweight are less likely to give birth to heavier children while those that were overweight or obese are more likely to give birth to children with heavier weights compared with mothers with normal BMI.

Keywords Proportional Odds Ratio, Nigeria Demographic and Health Survey, Wealth Index, Cut-off Points, Cumulative Logistic Regression

1. Introduction

Child's weight at birth has been shown to be associated with child's and maternal health; which in turn could be a determining factor of maternal and child mortality before, during and after birth. This may also be related to many factors, both physical and physiological. Among such factors that have been investigated in the past were maternal and paternal weights and heights, ethnicity, gestational age, birth order, maternal education, mother's age at the birth of child and race[1][2][3][4]. Other possible determinants of child's weight at birth that have been considered in literature were: paternal education, socio-economic status, prenatal care, method of delivery (either normal or through caesarean), child's sex, maternal smoking status, consumption of alcohol, and use of psychoactive drugs duringpregnancy[5][6][7][8][9]. It was observed that maternal weight had a greater influence on birth weight, while maternal and paternal height contributions were similar in nature[2]. Furthermore, weight and height of father and mother contributed equally to infant's weight gain.

Low birth weight (LBW) i.e. birth weight less than 2.5 Kilograms (KG), as a result of preterm birth or intrauterine growth retardation, is the strongest single factor associated with peri-natal, neo-natal, post-natal and infant mortality. Birth weight is related to health outcomes in childhood, such as neurological deficits and lower cognitive skills[10][11] as well as in adulthood; such as high blood pressure, diabetes, coronary heart disease and stroke[12][13][14][15]. LBW remains a substantial public health concern even in industrialized countries. It is more common among blacks than whites[16]. In addition, socio-economic factors have been suggested in literature[5][17]. Worldwide, it is estimated that 15.5% of all live birth per year are LBW, and more than 95% of LBW infants are born in developing countries[18]

Birth weight is also an important determinant of weight gain after birth. While low birth weight is associated with increased risk of morbidity and mortality in newborns and during infancy, excessive weight is associated with decreased maternal amino acids[19] Decreased foetal growth may result from a limitation in the nutrient supply to the foetus. Research has also linked small size at birth to

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increased risk of heart disease and diabetes later in life[15] In addition, poverty has been shown to be a determining factor of maternal and child health[20]. Findings from a study comparing siblings who were born with different weights and who experienced different economic circumstances at various points in their lives linked genetics and poverty as powerful factors in low birth weight. Findings from other studies have demonstrated that a combination of poverty and a family history of low birth weight significantly increase the likelihood that a baby will be born underweight.

2. Materials and Methods

2.1. Data Collection

The principal objective of the 2003 NDHS was to provide current and reliable data on fertility and family planning behaviour, child mortality, children's nutritional status, the utilization of maternal and child health services, as well as knowledge and attitudes towards HIV/AIDS. A related objective was to provide as many of these key indicators as possible for urban and rural areas separately. The population covered by the 2003 NDHS was defined as the universe of all women aged 15-49 years and all men aged 15-59 years in Nigeria. A probability sample of households was selected and all women aged 15-49 years identified in the households were eligible to be interviewed. In addition, in a sub-sample of one-third of the households selected for the survey, all men aged 15-59 years were eligible to be interviewed[21].

2.2. Methods

Consider a regression situation where the outcome variable on size of child at birth, say Y_i, i = 1, ..., n, is measured on an ordinal scale. A cumulative logistic regression model is suitable for this outcome. This is the most widely used model in ordinal regression. Suppose Y_i has k categories together with a vector of discrete or continuous covariates $\boldsymbol{x}_i$. Marginal probabilities for Y_i are related to vector of covariates $\boldsymbol{x}_i$ by a cumulative logistic model

$$g\{pr(Y_i \le r \mid \mathbf{x}_i)\} = \theta_r + \mathbf{x}'\boldsymbol{\gamma}, \qquad \mathrm{r} = 1,\ldots,\mathrm{k}-1, \quad (1)$$

for some suitable link function g, ordered threshold (cut-point) parameters $\theta_1<\ldots<\theta_{k-1}$ and a vector γ of covariate effects. A logit link function

$$\frac{p(Y_i \le r \mid x_i)}{p(Y_i > r \mid x_i)} = \exp(\theta_r + \mathbf{x}'\boldsymbol{\beta}) = \exp(\theta_r)\exp(\mathbf{x}'_{\mathrm{i}}\boldsymbol{\beta}), \quad (2)$$

$$\mathrm{r} = 1,\ldots,\mathrm{k}\text{-}1$$

was assumed. Details of many ordered response models are discussed in[22]. The commonly used model in the ordinal regression is based on the category boundaries or threshold (cut-point) approach. Therefore, θ_r are equivalent to separate intercepts for each cut-point. The parameter $\boldsymbol{\beta}$ refers to the effect of $\boldsymbol{x}_i$ on the log odds of Y_i, controlling for other covariates.

For all births during the five-year period preceding the survey, mothers were asked about their perception of the child's size at birth. They were then asked to report the actual weight in kilograms if the child had been weighed after delivery. It is not surprising that with the majority of deliveries occurring at home in Nigeria, the vast majority of newborns were not weighed at birth. Birth weight was reported for one in seven births in the preceding five years. The same proportion of mothers said that their newborns were weighed but they did not remember the weight[21]

Consequently, using the actual weight at birth variable for modelling purposes will result into spurious and erroneous inferences. A proxy variable that permitted mothers to describe child's weight in terms of *very small, smaller than average, average, larger than average and very large* was used. In this case, mothers were able to describe sizes of their children at birth for 5 043 (98.0%) children. Information on this was missing in only about 1.8% of the respondents. This is tolerable enough to permit reasonable analyses. Furthermore, there was no clear-cut pattern for the missing variables according to maternal educational attainment, place of residence or geopolitical zones where mothers resided.

We investigated the consistency of the subjective description of child's size at birth by creating a dataset for the respondents who could recall the actual child's birth weight by running some analyses. Selecting those that described their children's weight at birth to be average, we ran some tests of comparison of means (2-sample independent t-test and ANOVA test) according to some demographic characteristics such as place of residence (rural/urban), geopolitical zones, level of educational attainment and wealth index. Findings revealed that there was no significant difference (p>0.05). With this, one can assume that the subjective description of child's size at birth was fairly understood by the respondents. Therefore, for the purpose of this paper, we chose to use the ordinal outcome and condensed the categories of the outcome variable into three: *small, average* and *large*. Analysis based on traditional common regression techniques could not be employed for this kind of outcome variable because of these ordered categories. Furthermore, the common practice of collapsing inherently continuous or ordinal variables into two categories could cause information loss that may potentially weaken the power to detect effects of explanatory variables and results in erroneous conclusion[22]. Therefore, modelling techniques that take cognizance of ordinal responses are suitable for this situation. As a consequence, cumulative logistic regression was used to explore possible relationship between weight at birth and other determining factors while controlling for wealth index and maternal nutritional status.

3. Results and Discussions

3.1. Results

The data shows that a larger proportion of female children were described to have weighed *very small* or *smaller than average* at birth compared with their male counterparts. Of the 5 138 children that were contained in this dataset, information on weight at birth was only available for 5 043 children. Almost 15% weighed below average and about 42% weighed above average while the remaining weighed about average. About seven in ten of the children domiciled in rural areas compared with slightly higher than three in ten in urban areas. More than half of the mothers (51.7%) had no formal education compared with less than 4% of mothers who had higher or tertiary education. The proportion of male and female children was approximately equal. Significant association was evidence between sex and child's weight at birth (Chi=37.98, p=0.000). Figure 1 presents the distribution of age at birth desegregated by sex.

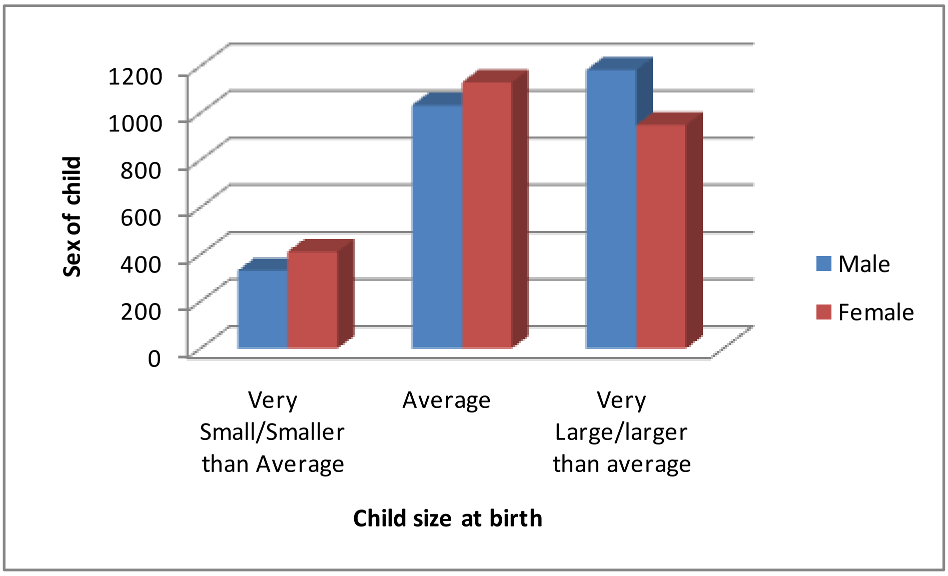

Figure 1. Bar charts describing the distribution of Child's size at birth disaggregated by sex

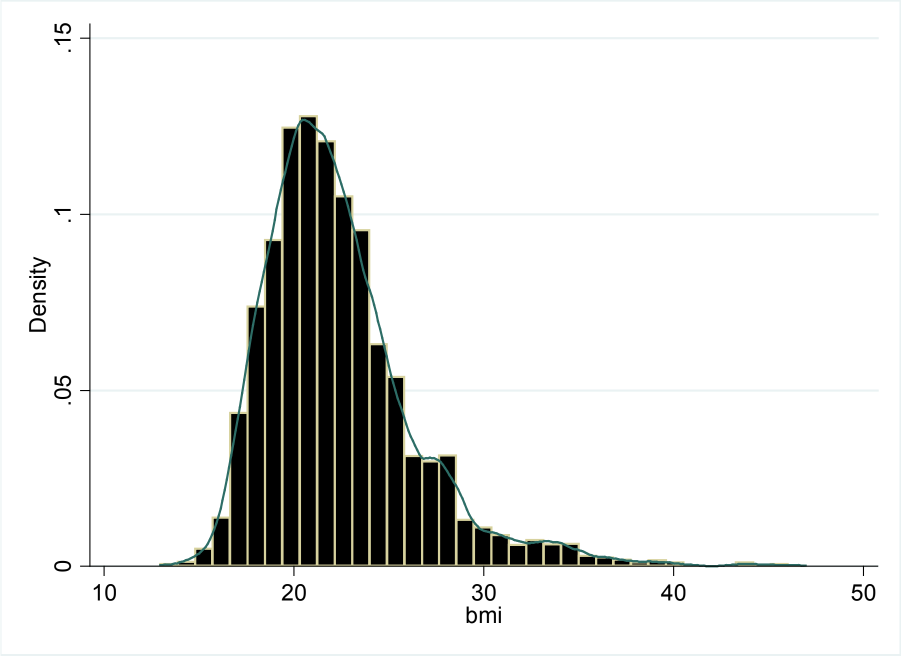

Figure 2. Histogram showing the distribution of BMI with the Kernel density (line) super-imposed

Considering the respondents' (maternal) BMI, almost 32% of mothers were underweight, overweight or obese. Figure 2 presents the distribution of mother's BMI. An approximately slightly right-skewed distribution was evident with a very small proportion of respondents being obese or having BMI greater than 40.00. From SPSS output, a kurtosis of 3.56 was obtained. These statistics further confirmed the departure of the distribution of BMI from normality assumption. The mean BMI of mothers was calculated as 22.38 with a standard deviation of 4.03. In this paper, we used World Health Organization's recommended classifications to evaluate the proportion of mothers who were underweight, normal, overweight or obese according to the 2003 NDHS data. Respondents with BMI lower than 18.5 were considered as being underweight, 18.5 to 24.99 as normal, 25.0 to 29.99 as overweight, while BMI of 30.00 and above was defined as obesity. From Table 1, about 13% of respondents were too thin (underweight), 14% were overweight and 5% were obese while the remaining 68% weighed what they should (normal). Exploratory analyses showed a strong association between respondents' BMI and current age (r=0.94). Furthermore, BMI varies by residence, education and household economic status (results not shown but available on request).

Table 1. Percentage distributions of the determinants of child's weight at birth

Determinants	Valid N (%)	Total N (%)	Missing N (%)
Locality			
Rural	3391(66.0)		
Urban	1747(34.0)	5138(100.0)	-
Region			
North East	876(17.0)		
North West	1336(26.0)		
South East	1540(30.0)		
South West	437(8.5)		
South South	486(9.5)	5138(100.0)	-
Educational attainment			
No Education	2655(51.7)		
Inc & Complete Pry	1248(24.3)		
Inc & Complete Sec	1070(20.8)		
Higher	165(3.2)	5138(100.0)	-
Child's Sex			
Male	2604(50.7)		
Female	2534(49.3)	5138(100.0)	-
Respondents' (mother) body mass index (BMI) -			
Underweight	650(12.7)		
Normal	3510(68.3)		
Overweight	729(14.2)		
Obese	249(4.8)	5138(100.0)	-
Mother's age at birth (MAB)			
Below 20 yrs	934(18.2)		
20 – 24 yrs	1447(28.2)		
25 – 34 yrs	2046(39.8)		
35 – 39 yrs	491(9.6)		
40 – 49 yrs	220(4.3)	5138(100.0)	-
Size of baby at birth			
Small	744(14.5)		
Average	2165(42.1)		
Large	2134(41.5)	5043(98.2)	95(1.8)
Wealth Index			
Poorest	1238(24.1)		
Poorer	1154(22.5)		
Middle	1010(19.7)		
Richer	982(19.1)		
Richest	754(14.7)	5138(100.0)	-
Tetanus injection during			
No Injection	1461(41.1)		
At least 1 injection	1961(55.2)	3422(66.6)	1176(33.4)*

*Due to large number of missing values, this variable was not included in the logistic regression

Table 2. Percentage distribution of child's weight at birth according to some selected background characteristics

Determinants	Small N (%)	Average N (%)	Large N (%)	Total[a] N (%)
Locality				
Rural	521(70.0)	1447(66.8)	1364(63.9)	3332(66.1)
Urban	223(30.0)	718(33.2)	770(36.1)	1711(33.9)
Region				
North East	253(34.0)	669(30.9)	380(17.8)	1302(25.8)
North West	182(24.5)	509(23.5)	833(39.0)	1524(30.2)
South East	55(7.4)	213(9.8)	136(6.4)	404(8.0)
South West	56(7.5)	187(8.6)	236(11.1)	479(9.5)
South South	59(7.9)	162(7.5)	239(11.2)	460(9.1)
North Central	139(18.7)	425(19.6)	310(14.5)	874(17.3)
Educational attainment				
No Education	448(60.2)	1110(51.3)	1041(48.8)	2599(51.5)
Inc & Complete Pry	164(22.0)	548(44.8)	512(41.8)	1224(24.3)
Inc & Complete Sec	120(16.1)	437(20.2)	501(23.5)	1058(21.0)
Higher	12(1.6)	70(3.2)	80(3.7)	162(3.2)
Child's Sex				
Male	332(44.6)	1034(47.8)	1184(55.5)	2550(50.6)
Female	412(55.4)	1131(52.2)	950(44.5)	2493(49.4)
Respondents' (mother) body mass index (BMI) -				
Underweight	130(17.8)	275(13.0)	239(11.4)	644(13.0)
Normal	499(68.4)	1463(69.3)	1375(65.3)	3337(67.5)
Overweight	72(9.9)	283(13.4)	361(17.1)	716(14.5)
Obese	28(3.8)	91(4.3)	130(6.2)	249(5.0)
Mother's age at birth (MAB)				
Below 20 yrs	149(20.0)	421(19.4)	350(16.4)	920(18.2)
20 – 24 yrs	210(28.2)	613(28.3)	602(28.2)	1425(28.3)
25 – 34 yrs	288(38.7)	824(38.1)	899(42.1)	2011(39.9)
35 – 39 yrs	57(7.7)	223(10.3)	195(9.1)	475(9.4)
40 – 49 yrs	40(5.4)	84(3.9)	88(4.1)	212(4.2)
Wealth Index				
Poorest	247(33.2)	543(25.1)	412(19.3)	1202(23.8)
Poorer	180(24.2)	502(23.2)	441(20.7)	1123(22.3)
Middle	133(17.9)	420(19.4)	447(20.9)	1000(19.8)
Richer	109(14.7)	404(18.7)	457(21.4)	970(19.2)
Richest	75(10.1)	296(13.7)	377(17.7)	748(14.8)

[a] This is based on the total number of children (5043) with information about their sizes at birth as provided by their mother

Figure 3 displays the bar-charts showing the frequency distributions of child's weight at birth according to household wealth index. A steady decrease in the proportion of children that weighed very small/smaller than average was evident from respondents in lowest to highest quintile of wealth index. Significant association was also observed between Child's weight at birth and household wealth index (chi = 93.3, p=0.000)

Table 2 presents the percentage distribution of child's weight at birth according to some demographic characteristics. A positive association between wealth index and child's weight at birth was evident. While the largest proportion of children born to households in the lowest quintile weighed smaller than average at birth, the smallest proportion of children born to households in the highest wealth quintile weighed smaller than average. Similar pattern of association was noticed for mother's nutritional status (BMI). The largest proportion of children born to mothers who were underweight weighed smaller than average at birth. Tables 3 and 4 present findings from the cumulative ordinal logistic models for 5-categorical and 3-categorical ordinal outcomes respectively. As can be seen, the direction of significance is similar in both models. We therefore, stuck to the discussion of results for the model with 3-ordinal outcomes. Note that while there are three response ordinal categories, 2 cut-points (thresholds) were created. A reference category was determined as the one with highest ordered level. In this case, Y=3 (i.e. child's weight at birth is large) was considered as the reference category. Intuitively, these thresholds provide opportunity for comparing the odds of a child's weight at birth being small with the odds of a child's weight at birth being large. Similarly, we can compare the odds of child's weight at birth being average with the odds of child's weight at birth being large. Positive threshold value implies large proportion of children in a particular category of the response variable; while negative threshold value is associated with low proportion for the respective category. For instance, an odds ratio of 0.243 for threshold for category 1 (i.e. threshold 1) implies that a smaller proportion of children were born with small weight at birth compared with those that were born with large weight. On the other hand, a slightly higher proportion of children were born with average weight compared with those that were born with large weight.

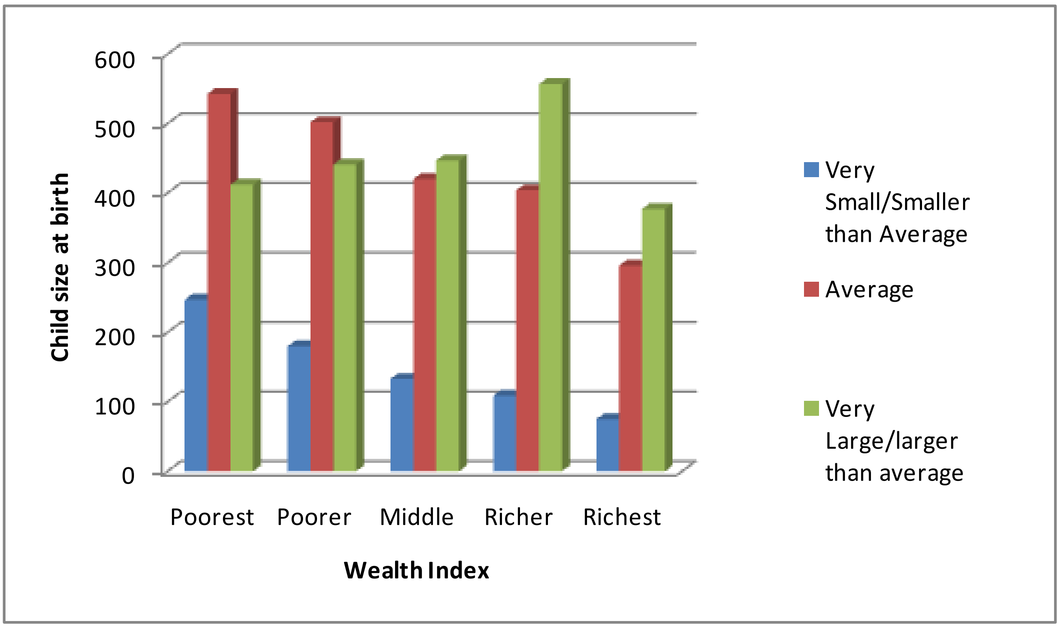

Figure 3. Bar charts describing the distribution of Child's size at birth and Wealth Index

Table 3. Results with odds ratio of ordinal logistic regression model for child's weight at birth using 3-ordinal outcome

Variables	odds ratio	Std. error	p-value	95% Confidence Interval	
Poorest (ref. category)	1.000				
Poorer	1.132	0.092	0.129	0.965	1.328
Middle	1.382	0.119	0.000	1.167	1.636
Richer	1.480	0.141	0.000	1.228	1.785
Richest	1.368	0.165	0.009	1.080	1.732
Rural (ref. category)	1.000				
Urban	1.029	0.072	0.683	0.898	1.179
No formal education (ref. category)	1.000				
Primary Education	1.150	0.085	0.060	0.994	1.329
Secondary Education	1.165	0.104	0.087	0.978	1.388
Higher Education	1.261	0.219	0.183	0.896	1.773
North Central (ref. category)	1.000				
South South	0.918	0.121	0.520	0.710	1.190
North East	0.624	0.073	0.000	0.497	0.783
North West	0.549	0.064	0.000	0.438	0.689
South East	1.413	0.164	0.003	1.126	1.773
South West	0.549	0.072	0.000	0.439	0.689
Female (ref. category)	1.000				
Male	1.388	0.076	0.000	0.419	0.705
Normal (ref. category)	1.000				
Underweight	0.799	0.067	0.008	.0678	0.942
Overweight	1.352	0.112	0.000	1.149	1.590
Obese	1.285	0.174	0.064	0.986	1.674
Mother's age at birth: <20years (ref.)	1.000				
Mother's age at birth: 20-24 years	1.162	0.096	0.069	0.988	1.365
Mother's age at birth: 25-34 years	1.273	0.101	0.002	1.090	1.487
Mother's age at birth: 35-39 years	1.250	0.138	0.044	1.006	1.553
Mother's age at birth: 40-49 years	1.176	0.180	0.290	0.871	1.587
Single Birth (ref. category)	1.000				
Multiple Birth	0.593	0.084	0.000	0.454	0.773
Threshold (cut-off) 1	0.243	0.139		-1.685	-1.141
Threshold (cut-off) 2	2.134	0.137		0.489	1.028

Table 4. Results with odds ratio of ordinal logistic regression model for child's weight at birth using 5- ordinal outcome

Variables	odds ratio	Std. error	p-value	95% Confidence Interval	
Poorest (ref. category)	1.000				
Poorer	0.909	0.072	0.229	0.778	1.062
Middle	0.743	0.062	0.000	0.631	0.838
Richer	0.715	0.065	0.000	0.598	0.855
Richest	0.785	0.090	0.034	0.627	0.982
Rural (ref. category)	1.000				
Urban	0.962	0.064	0.565	0.845	1.096
No formal education (ref. category)	1.000				
Primary Education	0.869	0.062	0.048	0.757	0.999
Secondary Education	0.820	0.070	0.020	0.694	0.969
Higher Education	0.770	0.126	0.012	0.559	1.062
North Central (ref. category)	1.000				
South South	1.203	0.147	0.130	0.947	1.528
North East	1.628	0.179	0.000	1.313	2.020
North West	1.721	0.191	0.000	1.313	2.020
South East	0.681	0.074	0.000	0.550	0.842
South West	1.822	0.232	0.000	1.419	2.338
Female (ref. category)	1.000				
Male	0.729	0.038	0.000	0.658	0.808
Normal (ref. category)	1.000				
Underweight	1.320	0.107	0.001	1.127	1.546
Overweight	0.737	0.058	0.000	0.632	0.859
Obese	0.754	0.096	0.026	0.587	0.967
Mother's age at birth: <20years (ref.)	1.000				
Mother's age at birth: 20-24 years	0.857	0.068	0.052	0.734	1.001
Mother's age at birth: 25-34 years	0.810	0.062	0.006	0.698	0.940
Mother's age at birth: 35-39 years	0.739	0.080	0.005	0.598	0.914
Mother's age at birth: 40-49 years	0.828	0.121	0.196	0.622	1.102
Single Birth (ref. category)	1.00				
Multiple Birth	1.684	0218	0.000	1.306	2.172
Threshold (intercept) 1	0.135	0.135		-2.266	-1.739
Threshold (intercept) 2	0.476	0.132		-1.000	-0.483
Threshold (intercept) 3	1.536	0.134		1.168	1.691
Threshold (intercept) 4	10.697	0.140		2.096	2.644

Significant and positive association of wealth index was evident with middle (OR=1.38, p<0.0001), higher (OR=1.48, p= p<0.0001), and highest (OR=1.37, p=0.009) wealth quintiles when compared with those in the poorest category of wealth index. Respondents in the upper wealth quintiles are significantly more likely to give birth to children with large weight compared with those in the lower quintiles (p=0.009). Furthermore, mothers that were too thin or underweight based on their BMI, were more likely to give birth to children with low birth weight (OR=0.80, p=0.008); while those that weighed more than they should (overweight: OR=1.35, p<0.0001; or obese: OR=1.29, p=0.065) were more likely to give birth to children with large weights when compared with mothers with normal BMI. Significant gender differentials were also found. Males were about 1.4 times (p<0.0001) more likely to have weights larger than their female counterparts at birth. Gender bias in child's weight at birth has been shown by other authors.

Age of mother at the birth of a child has also been shown to be of risk to pregnancy outcomes. Teenage mothers were more likely to give birth to children with low birth weight. Here, positive significant association was observed for mothers' age at birth and child's weight at birth. Children from mothers in the age range 25 to 39 years were about 1.26 times more likely to weigh more at birth compared with children from teenage mothers (p<0.05). Significant spatial pattern was observed at the level of geopolitical zones with p<0.05. This spatial variation, however, needs to be investigated further at a highly disaggregated level of states as information at this level could be masked. Multiple births are significantly associated with low birth weight compared with singleton births (OR=0.59, p<0.0001). However, the effects of mother's educational attainment and locality (rural/urban differential) were not significantly associated with child's weight at birth.

3.2. Discussion of Results

It was found that strong association exists between maternal and paternal educational attainment. Hence the inclusion of both variables resulted in multi-collinearity. Furthermore, inclusion of parity in the logistic regression models affected the significance of mother's age at the birth of child. Therefore, we prefer to present findings for models where paternal educational attainment and parity were excluded.

Gender bias in weight at birth has been previously reported by some authors. For instance, see[23][24][25][9][8][26] and[27] Findings from this paper, therefore, corroborate other authors. Male children were more likely to be heavier at birth compared with their female counterparts. Research also found that increases in a family's financial ability to meet its basic needs were directly linked to birth weight. According to New York Times of 9th January, 2002, findings from research linked genetics and poverty as powerful factors in low birth weight. The study authors (Dalton Conley and Neil G. Bennett) also found that a child who was born underweight and whose formative years were spent in poverty is considerably less likely to graduate from high school on time compared with other children. Therefore, education reforms should include supplementary support to children who were born underweight. Findings from our paper also reveal that children born to mothers in high wealth quintiles are less likely to have low weight at birth compared with those born to mothers in low wealth quintiles. These findings also suggest the needs for public health organizations to identify infants who are at high risk for low birth weight, as well as ways for them to reduce or counteract that risk.

The significant spatial effect in this paper reveals that there are substantial variations across all the six geo-political zones in terms of weight at birth of children according to the data from 2003 NDHS. Further investigation of such spatial variations should be properly explored so as to provide more insightful information for policy makers.

4. Conclusions

This approach has provided the opportunity to explore relationships between ordinal responses and determinants of child's weight at birth. Wealth indexand maternal nutritional status were found to be significantly associated with child's weight at birth. Mothers who belong to household with low wealth quintiles are more likely to give birth to children with lower birth weight.

The state of maternal and child health is one indicator of a society's level of development; as well as an indicator of the performance of the health care delivery system. As the country strive towards attaining universal comprehensive health care services for the citizens; especially for mothers and children, the issue of alleviating poverty is important. This has policy implications since a significant association exists between poverty and low birth weight. Health programmers need to design interventions to tackle both poverty and health simultaneously.

Female children were disproportionately associated with low birth weight. Therefore, mainstreaming of gender issues into health policies is desirable. Findings from this paper will provide opportunity to enhance appropriate policy formulation on gender issues.

To enhance proper child health's policy formulation, efforts should be targeted at an analytical tool which is capable of exploring spatial variation at a highly disaggregated level of states. This is due to the fact that policies are rather made at state level rather than geo-political zonal level. Furthermore, there are no two states within the same zone jointly developing policies. Through this, one could get better understanding of the situation of child health at state level.

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Conflict of Interest

The authors declare no conflict of interest. Furthermore, no financial support was received for this work as the data used were secondary data.

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