Environmental Factors, Neighbourhood Deprivation, And Under-Five Mortality In Nigeria: An Exploratory Spatial Data Analysis

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Citation

Abstract

Aim: to examine the impact of state-level access to basic environmental services and neighbourhood deprivation on under-five mortality rate

Methods: Using data from most recent Nigeria Demographic and Health Survey for a sample of 6029 live births between 1999 and 2003 and exploratory spatial data analyses, the study analyzed the state-level association between environmental, neighbourhood deprivation and under-five mortality rate.

Results: The spatial distribution of rates of under-five mortality rate was non-random and clustered with a Moran's I = 0.654 (p = .001). Spatial clustering suggested that North-east and North-west can be group as under-five mortality "hot-spot", and South-west, South-south, and South-east can be group as under-five mortality "cold-spot". The results outlined seemingly consistent finding that access to safe water, proper sanitation, and low pollution cooking fuel are important factors that can increase the chances of child survival.

Conclusion: The maps could be used by policy makers for targeting development efforts at a glance for resource allocation and scaling up preventive efforts to achieve Millennium Development Goal, MDG-4 to reduce by two-thirds, between 1990 and 2015, the under-five mortality and MDG-7 to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation. Multifaceted geographically differentiated intervention may represent a potentially effective approach for addressing issues related to child survival.

INTRODUCTION

Global under-five deaths over the last four decades have fallen from 20.4 million to 10.9 million annually. During this time deaths in sub-Saharan Africa almost doubled from 2.3 million to 4.5 million annually. The region's perilous situation is aggravated by the increasing number of under-five deaths due to HIV/AIDS and low immunization coverage as a result of weak health care systems. Despite a steady decline during this century, the Nigeria still has one of the highest infant mortality rates among developing nations. Researchers typically evaluate the characteristics of mothers or infants (usually from vital statistics data) as factors that elevate the risk of infant death. The associations between neighbourhood context and various indicators of physical health are receiving growing empirical attention, and multiple studies have shown that poor health is partly a function of macro-level socioeconomic disadvantage.

Neighbourhoods constitute a key determinant of socioeconomic disparities in health, as they shape individual opportunities and expose residents to multiple risks and resources over the life course. To expand our understanding of the aetiology of child health, the study argue that it is necessary to consider as additional risk factors the characteristics of the communities in which mothers and children live. Thus policy-related programs employed to address the relatively high U5MR in Nigeria may be less effective if based solely on evidence generated from individual-level of observation.

Goal 7 of the Millennium Development Goals (MDGs) addresses environmental sustainability, with a target (target 10) to “halve, by 2015, the proportion of people without...
sustainable access to safe drinking water and basic sanitation”. Water supply, sanitation and hygiene, given their direct impact on infectious disease and are important for preventing child mortality. Public health measures in developed countries, such as water purification, sanitary sewerage, trash and garbage collection, and reduction in food contaminations, have led to a substantial decline in morbidity and mortality. According to The world health report 2002 indoor air pollution is responsible for 2.7% of the global burden of disease. Indoor air pollution comprises a range of health-damaging pollutants, such as small particles and carbon monoxide, and is responsible for up to 1.6 million deaths every year, most of them due to acute respiratory infections (ARI) in children under five. Access to water and sanitation is a large element of the definition of decent, safe housing. Moreover, access to water and sanitation has large direct and indirect impacts on children’s health: Many of the most pervasive diseases are water related. The WHO estimates that water-related diseases account for 4% of all deaths and 5.7% of the total disease burden.

Policy-makers and researchers often want to know the distribution of disease by geographical region, or association with environmental factors. In this regard, mapping risk variations in under-five mortality is an invaluable tool. Further, mapping the U5MR can help improve the targeting of scarce resources for public health interventions. Therefore, the main objective of this study was to examine the impact of state-level access to basic environmental services and neighbourhood deprivation on under-five mortality. The study focused on four aspects of neighbourhood that may play a key role in moderating the variation in risk of under-five mortality: neighbourhood environmental and sanitation disadvantages; maternal socioeconomic disadvantages; inequalities in health care service utilization, and household competition for nutritional resources. The second objective was to examine and describe states variation and spatial clustering of U5MR.

MATERIALS AND METHODS

DATA SOURCE
Analysis of data in this study was based on 6029 children aged 0-59 month(s) included in Nigeria Demographic and Health Survey (NDHS) in 2003. Methods used in the NDHS have been published elsewhere. The NDHS collected demographic, socio-economic, and health data from nationally-representative sample of 7620 women aged 15-49 years in 7864 households included in the survey.

VARIABLES

DEPENDENT VARIABLE
Each woman interviewed in the survey was asked to provide a detailed history of all her live births in chronological order, including sex of the child, date of birth, survival status, age of the child on the date of interview if alive, and if not alive, age at death of each live birth. These data from the birth histories were used to calculate under-five mortality rate, defined as the probability of dying between birth and five years of age, using a synthetic cohort life table. The rate is expressed as deaths per 1000 live births.

ENVIRONMENTAL FACTORS
The environmental variables of interest in the current study are access to water, sanitation, and cooking fuel. The definition of “safe water” used in this analysis tries to capture both aspect of water quality and availability. It includes piped water – whether inside or outside the compound – as well as water from a well, as long as the well is protected. To capture the overall sanitary environment surrounding a household this study takes into account the disparities in access between urban and rural population. The definition of “proper” sanitation is defined as access to a flush toilet and ventilated improved pit latrine. Cooking fuel type was defined as low pollution fuel and high pollution fuel. High pollution fuel includes solid fuel: biomass fuels (wood, dung, agricultural residues)

MATERNAL SOCIOECONOMIC DEPRIVATION INDEX
Socioeconomic deprivation was operationalized with a principal component comprised of the proportion of: mothers with no education, residing in rural areas, unemployed, and living below the poverty level (asset index below 20% poorest quintile). A standardized score, mean ( ) = 0, standard deviation (SD) = 1 was generated from this index; with higher scores indicative lower socioeconomic status.

CHILD DEPRIVATION INDEX
Childhood deprivation index was operationalized with a principal component comprised of the proportion of: children low birth weight, not breast fed, with risky birth interval, children from households with more than four under-five children, and children with high birth order. A standardized score, = 0, SD = 1 was generated from this
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index; with higher scores indicative higher childhood deprivation and increased household competition for nutritional resources.

HEALTH SERVICE INDEX

Use of health services index estimated by principal component analysis. The indicator combines skilled birth attendance, antenatal care and proportion of recommended vaccinations. The age schedule from the Expanded Program on Immunization set by the WHO was used: BCG at birth, DPT and Polio at 2, 3 and 4 months and measles at 9 months. A standardized score, $= 0, SD = 1$ was generated with higher scores indicative lower health service utilization.

UNIT OF ANALYSIS

The state was unit of analysis. Therefore, the interpretation was limited to state-level associations and did not make inferences about individual-level associations to avoid cross-level bias or ecological bias.

STATISTICAL ANALYSIS

A three step process is followed in conducting the exploratory spatial data analysis (ESDA):

(i) Visualization: first the spatial distribution of under-five mortality rate (U5MR) was visualized. For conducting a GIS-based analysis on the spatial distribution of U5MR, the state-level polygon map was obtained, on which the state-level point layer containing information regarding latitudes and longitudes of central points of each state was created. U5MR was matched to the state-level layers of polygon and point by administrative code. To evaluate the status of each neighbourhood, spatially smoothed prevalence was obtained by means of spatial empirical Bayes estimation. Based on U5MR estimates, all states were grouped into three quintiles: low risk area, intermediate area, and high-risk area. In order to assess the risk of U5MR in each state, an excess hazard map was produced. The excess hazard represents the ratio of the observed U5MR in each state over the average U5MR of all high risk areas.

(ii) Next, non-spatial descriptive statistics were deployed. The relationship between state-level selected explanatory factors and U5MR was studied using the Pearson product–moment correlation.

(iii) ESDA was completed. The ESDA focused on two aspects of the spatial pattern: the overall “univariate” local spatial clustering in U5MR and the bivariate spatial relationship between U5MR and selected explanatory factors. The spatial pattern of U5MR was analyzed using Univariate Moran Scatter plot. Luc Anselin’s LISA (local indicator of spatial association), which can be seen as the local equivalent of Moran’s $I$. For each location, LISA values allow for the computation of its similarity with its neighbours and also test its significance. The bivariate spatial relationship between state-level environmental factors (as measured by proportion of households with proper toilet facilities, safe water source, low pollution cooking fuel, and U5MR was studied using bivariate Moran’s $I_{14}$. The bivariate LISA (BiLISA) Moran's $I$ “gives an indication of the degree of linear association (positive or negative) between the value for one variable at a given location $I$ and the average of another variable at neighbouring locations.” Similar to LISA, BiLISA suggests two classes of positive spatial correlation, or spatial clusters (High-High and Low-Low), and two classes of negative spatial correlation, or spatial outliers (High-Low and Low-High). Inference for Moran’s $I$ was based on a permutation approach, in which a reference distribution is calculated for spatially random layouts with the same data as observed $^{15}$.

RESULTS

SPATIAL DISTRIBUTION

Spatially smoothed map of under-five mortality rate (U5MR) was created, smoothed U5MR present a clearer patterns and show clearly where the problem is most severe (Figure 1). Among the 37 states, 13 states belonged to low risk zone and 12 states each belonged to intermediate and high risk zone (Figure 1).

Figure 1

Figure 1: Spatially smoothed percentile map of under-five mortality rate in Nigeria, 1999-2003

The U5MR was higher in Northern parts of Nigeria and lower in the southern parts of Nigeria. The excess hazard map (Figure 2) showed distribution of the excess risk. States
in white colour had lower U5MR than expected, as indicated by excess risk values less than 1. In contrast, states in red had prevalence U5MR higher than expected as indicated (Figure 2).

Figure 2
Figure 2: Excess hazard map of under-five mortality rate in Nigeria, 1999-2003

SPATIAL AUTOCORRELATION
The result of Local Moran’s I show statistically significance spatial autocorrelation (Moran’s I = 0.654, p = .001) (Figure 3). North West and North East of Nigeria belongs to High-High (“hot spot”) cluster with similar neighbours. These are locations with higher U5MR. The locations marked in blue belong to Low-Low (“cold spot”) cluster. These are states with lower U5MR with similar neighbours.

Figure 3
Figure 3: Local Indicator of Spatial Association (LISA) cluster map for under-five mortality rate in Nigeria, 1999-2003

BIVARIATE ASSOCIATIONS

ASPATIAL
Descriptive statistics of the selected state-level explanatory variables are shown in Table 1. The distribution of selected variables varied greatly across the 37 states.

Figure 4
Table 1: Descriptive statistics of the state-level explanatory variables and hypothesized associations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD)</th>
<th>Min, Max</th>
<th>Hypothesized association</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Factor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proper sanitation</td>
<td>12.9 (14.3)</td>
<td>0.0, 59.1</td>
<td>Negative (-)</td>
</tr>
<tr>
<td>Safe water</td>
<td>72.2 (29.2)</td>
<td>0.0, 67.7</td>
<td>Negative (-)</td>
</tr>
<tr>
<td>Low pollution fuel</td>
<td>20.8 (21.9)</td>
<td>0.0, 92.8</td>
<td>Negative (-)</td>
</tr>
<tr>
<td>Neighbourhood deprivation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal deprivation</td>
<td>0.0 (1.0)</td>
<td>-2.2, 2.8</td>
<td>Positive (+)</td>
</tr>
<tr>
<td>Health service utilization</td>
<td>0.0 (1.0)</td>
<td>-1.7, 2.2</td>
<td>Positive (+)</td>
</tr>
<tr>
<td>Childhood deprivation</td>
<td>0.0 (1.0)</td>
<td>-1.8, 1.8</td>
<td>Positive (+)</td>
</tr>
</tbody>
</table>

Table 2 describes the correlation between U5MR and selected factors. As expected, there was statistically significant negative correlation between percentage of households with proper toilet facilities (Pearson’s r = -0.45, p = .006), safe water source (r = -0.33, p = .047), and low pollution fuel (r = -0.56, p = .001). In addition, there was strong and positive statistically significant correlation between U5MR and state-level maternal deprivation (r = 0.62, p = .001), health service utilization (r = 0.60, p = .001), and childhood deprivation (r = 0.52, p = .001) indices.

Figure 5
Table 2: Bivariate associations between under-five mortality, selected state-level environmental, and neighbourhood deprivation variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Aspatial</th>
<th>Spatial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pearson’s correlation</td>
<td>95% CI</td>
</tr>
<tr>
<td>Environmental Factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proper sanitation</td>
<td>-0.45 (-0.67, -0.24)</td>
<td>.001</td>
</tr>
<tr>
<td>Safe water</td>
<td>-0.33 (-0.59, -0.06)</td>
<td>.047</td>
</tr>
<tr>
<td>Low pollution fuel</td>
<td>-0.56 (-0.75, -0.37)</td>
<td>.001</td>
</tr>
<tr>
<td>Neighbourhood deprivation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal deprivation</td>
<td>0.62 (0.37, 0.79)</td>
<td>.001</td>
</tr>
<tr>
<td>Health service utilization</td>
<td>0.60 (0.33, 0.77)</td>
<td>.001</td>
</tr>
<tr>
<td>Childhood deprivation</td>
<td>0.52 (0.24, 0.72)</td>
<td>.001</td>
</tr>
</tbody>
</table>

SPATIAL
Table 2 also describes the bivariate Moran’s I between U5MR and selected variables using rook contiguity matrix.
The bivariate Local LISA Moran's I statistic for spatial correlation between percentages of households with proper toilet facilities, safe water source, and low pollution fuel are -0.39 (p=.001), -0.25 (p=.001), and -0.57 (p=.001) respectively, indicating a significant negative spatial relationship percentages of households with proper toilet facilities, safe water source, low pollution fuel, and U5MR. Bivariate LISA cluster map indicates two classes of negative spatial correlations (high-low and low-high) and two classes of positive spatial correlations (low-low and high-high) (Figures 4A, 4B, & 4C). The Low-high cluster is seen mainly in the northern part of Nigeria, in these states low percentages of households with proper toilet facilities, safe water source, and low pollution fuel are significantly correlated with high U5MR. Whereas, the high-low cluster seen mainly in the southern part are states significant correlation between high percentages of households with proper toilet facilities, safe water source, and low pollution fuel and low neighbouring U5MR.

**Figure 6**

Figure 4: Bivariate LISA cluster map for percentages of households with proper sanitation, safe water source, and low pollution cooking fuel; and spatial lag of under-five mortality rate in Nigeria, 1999 – 2003

The bivariate Local LISA Moran's I statistic for spatial correlation between state-level maternal deprivation, health service utilization, childhood deprivation indices, and spatial lag of U5MR are 0.62 (p=.001), 0.60(p=.001), and 0.52 (p=.001) respectively, indicating a significant positive spatial relationship between state-level maternal deprivation,
health service utilization, childhood deprivation indices and U5MR (Table 2). States marked in red colour (high-high cluster) exhibit positive correlation with higher U5MR (Figure 5A, 5B, & 5C).

**DISCUSSION**

**Figure 7**

Figure 5: Bivariate LISA cluster map for maternal socioeconomic deprivation, health service utilization, and childhood deprivation indices; and spatial lag of under-five mortality rate in Nigeria, 1999 – 2003
MAIN FINDINGS
This study has examined state-level associations between environmental factors (as measured by percentages of household with proper toilet facilities, safe water source, and using low pollution cooking fuel), neighbourhood deprivation (as measured by maternal socioeconomic deprivation, health service utilization, and childhood deprivation), and under-five mortality rate (U5MR). The results outlined above show some clear trends: the seemingly consistent finding that access to safe water, proper sanitation, and low pollution cooking fuel are important factors that can increase the chances of child survival. The topic is of extreme relevance for human development. The place where a child is born will be determinant in her life and death. If she sees the first day of light in a household without running water and a toilet facility, she will be more likely to die from risks associated to poor environmental conditions. Previous research has found that the two most important factors explaining the decrease in under-five fatality during the 1990s were water supply and sanitation. More recent studies have also confirmed this association

Another interesting finding in this study is evidence of geographical disparities in U5MR. The study found a clear and strong spatial structure at the state-level, with a higher U5MR appears mainly in the northern states and a lower U5MR is present in southern states. This finding is consistent with other studies that have examined regional variations and clustering in other childhood diseases in Nigeria.

POLICY IMPLICATIONS
The study findings have some important and relevant policy messages. The analysis of the geographic variation in U5MR in Nigeria is important. Such a focus is consistent with the Nigeria's national health initiative, which aims to reduce and ultimately eliminate health inequalities among gender, ethnic, socioeconomic, and geographic groups. A geographic analysis should help identify states and regions of the country that have a relatively high U5MR that may need to be particularly targeted with education and prevention programs. Multifaceted geographically differentiated intervention may represent a potentially effective approach for addressing issues related to child survival.

CONCLUSIONS
In summary, this study found a clear and strong spatial structure of under-five mortality rate (U5MR) at the state-level, with a higher U5MR appears mainly in the northern and eastern states and a lower U5MR is present in southern and western states. Environmental factors and neighbourhood deprivation may contribute to the clustering of U5MR in Nigeria states.

CONTRIBUTOR'S LIST
OAU had major role in study conception, data extraction, analyses, and writing of the manuscript

ACKNOWLEDGEMENTS
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