Health Policy and Planning, 31, 2016, 1212–1224
doi: 10.1093/heapol/czw053
Advance Access Publication Date: 20 May 2016
Original Article

Explaining socio-economic inequalities in immunization coverage in Nigeria

John E. Ataguba,[1]* Kenneth O. Ojo [2] and Hyacinth E. Ichoku[3]

[1]Health Economics Unit, School of Public Health and Family Medicine, Health Sciences Faculty, University of Cape Town, Anzio Road, Observatory, 7925, South Africa, [2]Centre for Health Economics and Development, Abuja, Nigeria and [3]Department of Economics, University of Nigeria, Nsukka, Nigeria

*Corresponding author. Health Economics Unit, School of Public Health and Family Medicine, Health Sciences Faculty, University of Cape Town, Anzio Road, Observatory, 7925, South Africa. E-mail: John.Ataguba@uct.ac.za

Accepted on 11 April 2016

Abstract

Globally, in 2013 over 6 million children younger than 5 years died from either an infectious cause or during the neonatal period. A large proportion of these deaths occurred in developing countries, especially in sub-Saharan Africa. Immunization is one way to reduce childhood morbidity and deaths. In Nigeria, however, although immunization is provided without a charge at public facilities, coverage remains low and deaths from vaccine preventable diseases are high. This article seeks to assess inequalities in full and partial immunization coverage in Nigeria. It also assesses inequality in the 'intensity' of immunization coverage and it explains the factors that account for disparities in child immunization coverage in the country. Using nationally representative data, this article shows that disparities exist in the coverage of immunization to the advantage of the rich. Also, factors such as mother's literacy, region and location of the child, and socio-economic status explain the disparities in immunization coverage in Nigeria. Apart from addressing these issues, the article notes the importance of addressing other social determinants of health to reduce the disparities in immunization coverage in the country. These should be in line with the social values of communities so as to ensure acceptability and compliance. We argue that any policy that addresses these issues will likely reduce disparities in immunization coverage and put Nigeria on the road to sustainable development.

Key words: Full immunization; immunization coverage; inequality; Nigeria; partial immunization

Key Messages

- Children from richer households, from the urban areas, and from richer geo-political zones in Nigeria are more likely to be fully immunized compared with their counterparts.
- In Nigeria, inequality in full immunization coverage is to the advantage of the rich while inequality in partial or no immunization coverage suggests that poor children generally are either partially immunized or receive no immunization.
- Factors such as mother's literacy, region and location of residence, and socioe-conomic status significantly explain disparities in immunization coverage in Nigeria.
- There is a need to address the factors that account for inequality, and other social determinants of health, to reduce the disparities in immunization coverage in Nigeria.

Introduction

In the past two decades, there has been a significant reduction in under-5 deaths globally. However, in 2013 over 6 million children younger than 5 years died from either an infectious cause or during the neonatal period (Liu *et al.* 2015). Over 51% of the deaths are due to infectious causes such as pneumonia, diarrhoea, malaria, meningitis and measles while about 44% of the deaths occurred during the neonatal period due to preterm birth complications, intrapartum-related complications, and neonatal sepsis (Liu *et al.* 2015). A greater proportion of childhood deaths occur in developing countries, especially in sub-Saharan Africa (Black *et al.* 2003; Bryce *et al.* 2005; Lawn *et al.* 2005; Liu *et al.* 2015). In fact it is projected that by 2030 about 60% of childhood deaths will occur in sub-Saharan Africa (Liu *et al.* 2015). Also growing inequality exists in childhood deaths between sub-Saharan Africa and industrialized economies. In 1990 there was a 20-fold difference in the child mortality ratio between sub-Saharan Africa and industrialized countries and this grew to a 29-fold difference by the year 2000 (Black *et al.* 2003).

Although the causes of childhood deaths may be different between countries, requiring context specific interventions (Black *et al.* 2003; Liu *et al.* 2015), it is indisputable that access to immunization *inter alia* is an important determinant of child health (Bryce *et al.* 2005) because it protects children from many deadly diseases. In fact immunization against measles is an indicator for monitoring the Millennium Development Goal (MDG) no. 4 (United Nations 2001). Between 1999 and 2005 it was estimated that immunization helped avert about 7.5 million deaths from measles in Africa (UNICEF 2007). However in many countries, especially in developing countries, vaccine-preventable diseases still claim many lives of children (Jones *et al.* 2003; Lim *et al.* 2008; Liu *et al.* 2015).

In Nigeria, government's policy is to provide 'immunization services and potent vaccines free of charge to all population at risk of vaccine preventable diseases' either through public facilities or other collaborating private facilities (National Primary Healthcare Development Agency 2009: 7). In fact the country's revised National Immunization Policy aims to 'improve and sustain routine immunization coverage of all antigens to 90% by the year 2020' (National Primary Healthcare Development Agency 2009). However, the coverage rate of various vaccines is still low (Federal Ministry of Health 2013). A brief overview of the country's immunization schedule for children under 12 months is shown in Box 1.

Box 1 Immunization schedule for children under 1 year in Nigeria

First contact: at birth—BCG; OPV0
Second contact: 6 weeks of age—Pentavalent 1 (DPT, HBV and Hib); OPV1
Third contact: 10 weeks of age—Pentavalent 2 (DPT, HBV and Hib); OPV2
Fourth contact: 14 weeks of age—Pentavalent 3 (DPT, HBV and Hib); OPV3
Fifth contact: 9 months—Measles; yellow fever
Source: National Primary Healthcare Development Agency (2009)

Up until mid-2014, the incidence of wild poliovirus, a vaccine preventable disease, was high in Nigeria and it was mostly reported in northern Nigeria (Yahya 2007; Etsano *et al.* 2015). Innovative strategies that helped reduce the incidence of polio in Nigeria included directly observed polio vaccination, social mobilization using volunteer community mobilizers, traditional and religious leaders, and polio survivors (Etsano *et al.* 2015). Although progress has been recorded with polio eradication in Nigeria, a substantial number of deaths associated with measles and other vaccine-preventable deaths in Africa occur in the country (Norheim *et al.* 2015). In fact Nigeria records one of the lowest childhood immunization coverage rates in the world (UNICEF 2015). Also, Nigeria is among the top 5 countries with the highest number of under-5 and neonatal deaths in 2013 (Liu *et al.* 2015). These meant that Nigeria was not on track in achieving the fourth MDG by 2015. These issues have continued to raise concerns for Nigerians and the health system in general especially in the context of the current post-2015 sustainable development goals. There are also variations across the geopolitical zones in the country with regards to immunization coverage and child health indicators and these are in line with the wealth of the various regions (National Population Commission and ICF International 2014). Nigeria presents as a significant country within the African continent given its share size. Therefore, poor immunization coverage and wide inequalities in immunization within the country will have a substantially negative impact on the continent's health indicators.

Given this background, this article uses nationally representative household data to assess inequalities in full and partial immunization coverage in Nigeria. It also assesses inequality in the intensity of immunization coverage in the country. Further, it attempts to explain the factors that account for the disparities in child immunization in the country. This is particularly important because to address some of these issues, there needs to be a clear understanding of the pattern and intensity of inequalities in immunization coverage in the country as well as regional disparities including the factors that account for such disparities. These will assist to develop policies to increase immunization coverage and address disparities that exist in immunization coverage.

Methods

Data

The dataset used for the study is the 2006 nationally representative Core Welfare Indicators Questionnaire Survey (CWIQ) conducted by the Nigerian National Bureau of Statistics. It is designed to complement the 2003/04 National Living Standards Survey (NLSS). Unlike the NLSS, CWIQ is a quick and rapid survey that elicits non-monetary welfare indicators. These are relevant for *inter alia* quick assessment of poverty and deprivation in Nigeria. Other datasets such as the Demographic and Health Survey (DHS) or the Multiple Indicator Cluster Survey (MICS) could be used as well. However, the CWIQ survey was preferred because the NLSS has recently been combined with it to form the Harmonized Nigeria Living Standard Survey (HNLSS) (National Bureau of Statistics 2014). This is among other things because the HNLSS has detailed information on expenditure while the CWIQ does not. Because the HNLSS now contains detailed information on expenditure, as opposed to the DHS or the MICS, it will become more suitable for monitoring socio-economic inequalities trends into the future. The CWIQ, just like the NLSS and the HNLSS uses a multi-stage sampling procedure that allows for both national and sub-national analyses as well as rural and urban comparisons. The first stage selects all the 774 local government areas (LGAs) in the country. Subsequently, a two-stage cluster sampling strategy is employed in data collection within each LGA. In the next stage 10 enumeration areas (EAs) are selected from each LGA while the last stage involved a selection of 10 housing units (or households) from each EA selected. In total, about 75 900 households, representing a coverage rate of about 98%, are completely enumerated.

A sub-dataset of children is created comprising information on about 42 000 children aged between 0 and 59 months. Only about 34 859 children (representing 83% of the children) are aged between 12 and 59 months. The latter sub-sample of 34 859 children is selected for analysis[1]. In the analyses, three mutually exclusive categories of children are identified: (a) fully immunized children (i.e. children aged 12–59 months that received all of the following 12 vaccines[2]—measles, BCG, DPT1-3, OPV0-3, yellow fever, MMR and vitamin A), (b) partially immunized children (i.e. those that received at least one but not all of the 'vaccines') and (c) never immunized (i.e. those that have never been vaccinated since birth).

A fourth group is formed because the group of partially immunized children could range from children receiving only one 'vaccine' or antigen to children receiving eleven 'vaccines'. This group measures the intensity of immunization and is defined as the proportion of the total 'vaccines' received by each child (i.e. relative to the number of 'vaccines' that the child should have received).

Constructing a measure of socio-economic status

Generally, there are debates as to the appropriate measure for socio-economic status (SES) (Brockerhoff and Hewett 2000; Ichoku 2011). Wagstaff and Watanabe (2003) reporting on a multi-country study of child health inequality conclude that child health inequality is robust to the choice of SES measure. A counter evidence has however been recorded in the case of Kenya (Chuma and Molyneux 2009). In this article SES is assessed using the principal components analysis (PCA) approach (Filmer and Pritchett 2001). This is because the CWIQ data do not contain information on income or expenditure. A total of 20 relevant variables[3] are used to construct the index. These included a combination of assets ownership, access to utilities and infrastructure, housing characteristics, education and occupational status of household head. In order to avoid clumping and truncation, these variables are carefully and thoroughly selected based on the guidelines set out in Vyas and Kumaranayake (2006).

Briefly, the reliability of the socio-economic index constructed from the 2006 CWIQ data are assessed by comparing the density of per capita expenditure obtained from the 2003/04 NLSS data that contained reliable data on expenditure (Figure 1b and the density of the index Figure 1a). Interestingly, both distributions exhibit a similar pattern as they are generally skewed to the right.

Analytical methods

Child health inequality can be assessed using different measures (see Ataguba *et al.* 2011 for a discussion on various methods and their merits). This article however uses concentration indices and curves to assess the extent of inequality in immunization coverage in Nigeria. These measures are widely used because they are consistent with ranking individuals across SES; sensitive to changes in population distribution across SES and they are able to assess relative, as opposed to absolute inequality (Wagstaff *et al.* 1991; Kakwani *et al.* 1997). In order to reduce the confounding effects of some variables correlated with SES and immunization coverage, each immunization variable is 'indirectly' standardized by age and sex. This procedure attempts to correct the distribution of immunization coverage by comparing it with that expected of the actual age/sex distribution of children. It therefore produces the distribution of immunization coverage by SES conditional on the confounding variables (age and sex of the child) (Kakwani *et al.* 1997; O'Donnell *et al.* 2008). Direct standardization was not used in this article because it uses arbitrary age/sex groups that could alter the standardized concentration index according to the number of age/sex groups formed (Kakwani *et al.* 1997).

The unstandardized concentration index for an immunization variable[4] H is computed following Duclos and Araar (2006) as:

$$C_H = 1 - (\widehat{\xi}_H / \widehat{\mu}_H) \tag{1}$$

where $\widehat{\mu}_H$ is the weighted average of H; $\mathbf{x} = [x_1, x_2, \ldots, x_n]$ is a vector of SES; and $\mathbf{w} = [w_i, w_2, \ldots, w_n]$ is the vector of sampling weights. $\widehat{\xi}_H = \sum_{i=1}^{n} \left(((V_i)^2 - (V_{i+1})^2)/(V_1)^2 \right) h_i$; h_i (value of the immunization variable for child i); $V_i = \sum_{j=i}^{n} w_j$ and $x_1 \geq x_2 \geq \ldots x_{n-1} \geq x_n$.

Indirectly standardized concentration index of immunization coverage is estimated following the procedure outlined in O'Donnell *et al.* (2008). A simple OLS regression was fitted to the equation

$$\widehat{h}_i^X = \widehat{\alpha} + \sum_j \widehat{\beta}_j x_{ij} \tag{2}$$

where x_{ij} are the confounding variables—age and sex, and the prediction $\widehat{h}_i^X$ is obtained based on the estimated coefficients ($\widehat{\alpha}$ and $\widehat{\beta}_j$). Indirectly standardized immunization variable ($\widehat{h}_i^{IS}$) is obtained as

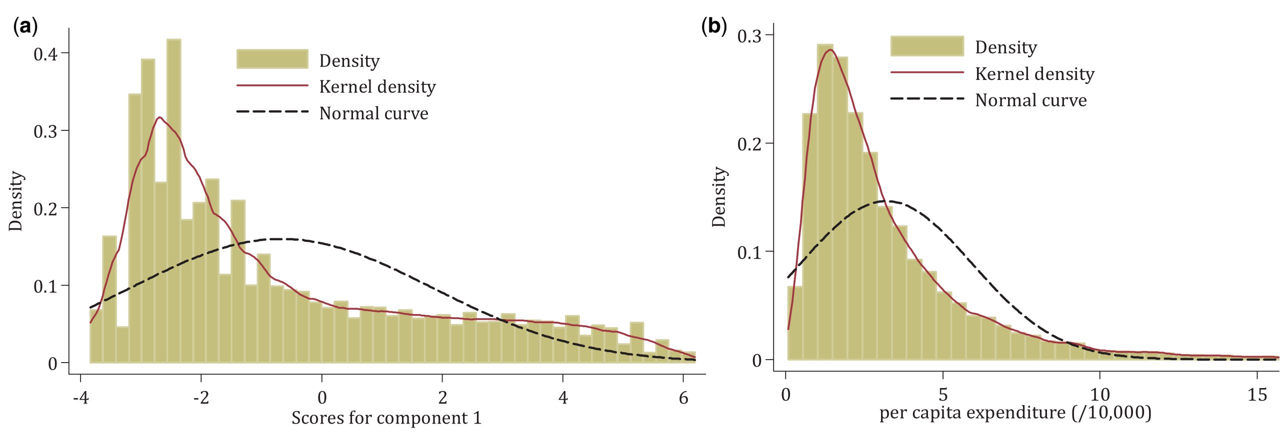

Figure 1. Comparing the distribution of socio-economic scores with the distribution of per capita expenditure. **(a)** Scores predicted based on PCA using the CWIQ. **(b)** Per capita expenditure (in Naira) based on the 2003/2004 NLSS.

$$\widehat{h}_i^{IS} = h_i - \widehat{h}_i^{X} + \mu_H \quad (3)$$

where μ_H is the mean of the respective immunization variable.

The standardized immunization variable ($\widehat{h}_i^{IS}$) is used to compute the indirectly standardized concentration index.

The value of the concentration index lies between −1 (i.e. for example the case of full immunization, it corresponds to a case where only the most socio-economically disadvantaged child is fully immunized) and +1 (a case where only the least socio-economically disadvantaged child is fully immunized). In general, a positive (negative) value for the concentration index indicates that the variable of interest (e.g. fully immunized children) are concentrated among the socio-economically advantaged (disadvantaged). A value of zero means that the variable of interest is evenly spread across all socio-economic groups. This could also result from a case where positive and negative effects cancel out across the SES distribution.

Wagstaff (2005) demonstrates that in the case of a binary variable (such as the three mutually exclusive groups) the concentration index does not have the usual bounds. It will lie between $(\mu_H - 1)$ and $(1 - \mu_H)$ and will require normalization by $(1 - \mu_H)$. However Erreygers (2009a,b) considers this as an *ad hoc* procedure and proposed another way of adjusting the standard concentration index in the case of ordinal data including dichotomous data. Erreygers (2009b) also notes that Wagstaff's (2005) *ad hoc* normalization 'blow[s] up the levels of measured inequality for distributions with either high or low means' (Erreygers 2009b: 523) as opposed that proposed in Erreygers (2009a).

Wagstaff (2009) has shown that Erreygers' (2009a) adjusted concentration index E_C is equivalent to

$$E_C = 4(\mu_H / b - a) \cdot C_H \quad (4)$$

where $(b - a)$ is the range of the variable of interest.

If we write Wagstaff's (2005) normalized index (W_C) as

$$W_C = C_H / (1 - \mu_H) \quad (5)$$

For a case of a binary variable, Ataguba *et al.* (2011) have shown that the Erreygers index E_C can be written equivalently as

$$E_C = 4W_C(\mu_H - \mu_H^2) \quad (6)$$

Equations (5) and (6) show that for an indicator variable, E_C is some weighted function of W_C (Ataguba *et al.* 2011).

Concentration curves that depict the cumulative share of child immunization coverage for children ranked by SES are transformed by taking the vertical difference between the concentration curve's coordinates and the corresponding coordinate on the line of equality (i.e. the 45° line). A positive (negative) difference signifies that, at that percentile, the concentration curve lies below (above) the line of equality. Overall, if the difference is consistently positive (negative) throughout the SES distribution, then the variable of interest is concentrated among the socio-economically advantaged (disadvantaged) groups (Phiri and Ataguba 2014). Analytic standard errors (SEs) and corresponding confidence interval bands are also computed around the estimated differences. The representations in Equations (5) and (6) are used to respectively construct Wagstaff's (2005) and Erreygers' (2009a) adjusted concentration curve coordinates and SEs.

Decomposing the concentration index of immunization coverage

Although concentration indices and corresponding curves are relevant in showing the extent of socio-economic related inequalities in immunization coverage, they do not explain the factors that contribute to observed inequalities. It is of great interest to know these factors, as they are crucial for policy and for addressing some of the underlying 'causes' of inequality. In order to address this concern inequality in immunization coverage can be explained by decomposing the concentration index (C_H). This article uses the method outlined in Wagstaff *et al.* (2003). The contribution of each factor to socio-economic related inequality in immunization is computed as the product of the sensitivity of child immunization with respect to each factor and the degree of socio-economic related inequality in each factor.

Wagstaff *et al.* (2003) show that the concentration index (C_H) in Equation (1) can be decomposed and written equivalently as:

$$C_H = \underbrace{\sum_{j=1}^{J} C_j(\beta_j \bar{z}_j / \mu_H)}_{\text{Deterministic}} + \underbrace{(GC_\varepsilon / \mu_H)}_{\text{Unexplained}} \quad (7)$$

where C_j ($\bar{z}_j$) is the concentration index (mean) of the jth contributing factor, GC_ε is the generalized concentration index of the error term (ε) and β_j is obtained from the following linearly additive equation that relates the contributing factors (z) to the immunization variable (h). The equation is given as

$$h_i = \alpha + \sum_j \beta_j z_{ij} + \varepsilon_i \quad (8)$$

where α and β_j are the coefficients to be estimated and ε_i is the error term.

The deterministic portion of the concentration index shown in Equation (7) is interpreted as the contribution of each contributing factor (z) to the concentration index (C_H) and it consists of two parts. It is a product of the concentration index of each contributing factor (C_J) and the elasticity of h_i with respect to z_j (i.e. $\eta_j = \beta_j \bar{z}_j / \mu_H$). The unexplained portion, computed as the residual in Equation (7), is the part of socio-economic inequality in child immunization that cannot be systematically explained by variations in the contributing factors across SES groups (Wagstaff *et al.* 2003).

The variables included in the decomposition are selected based on previous studies (see e.g. Wagstaff *et al.* 2003; Doorslaer and Koolman 2004), their relevance to understanding child health inequality in Nigeria and availability within the data set. These variables include age and sex of the child, rural or urban location, mother's literacy, quintiles of SES, and geopolitical zones dummies to pick geographical-specific determinants of immunization. For instance mother's education predicts child health inequality (Wamani *et al.* 2004). Also income and geographical factors influence immunization in Nigeria (Renne 2006).

It is not possible to write out analytical expressions to compute SEs for the components (i.e. elasticities and each contributing factor's contribution to the concentration index) of the decomposition in Equation (7). This was due to the way the various components are obtained. Therefore bootstrap methods (Efron and Tibshirani 1986; Efron 1987) are used in this article to obtain such SEs. In line with international practice a total of 1000 resamples are used for each estimate (StataCorp 2011: 195). To further avoid inconsistent estimates of bootstrap SEs (Cameron and Trivedi 2009), the full sampling structure of the data was taken into account. All statistical analyses are conducted using Stata 12 (StataCorp 2011).

Empirical results

Overall, as shown in Figure 2, only about 33% of children aged between 12 and 59 months are fully immunized while over 65% are partially immunized and <1% are never immunized. Full

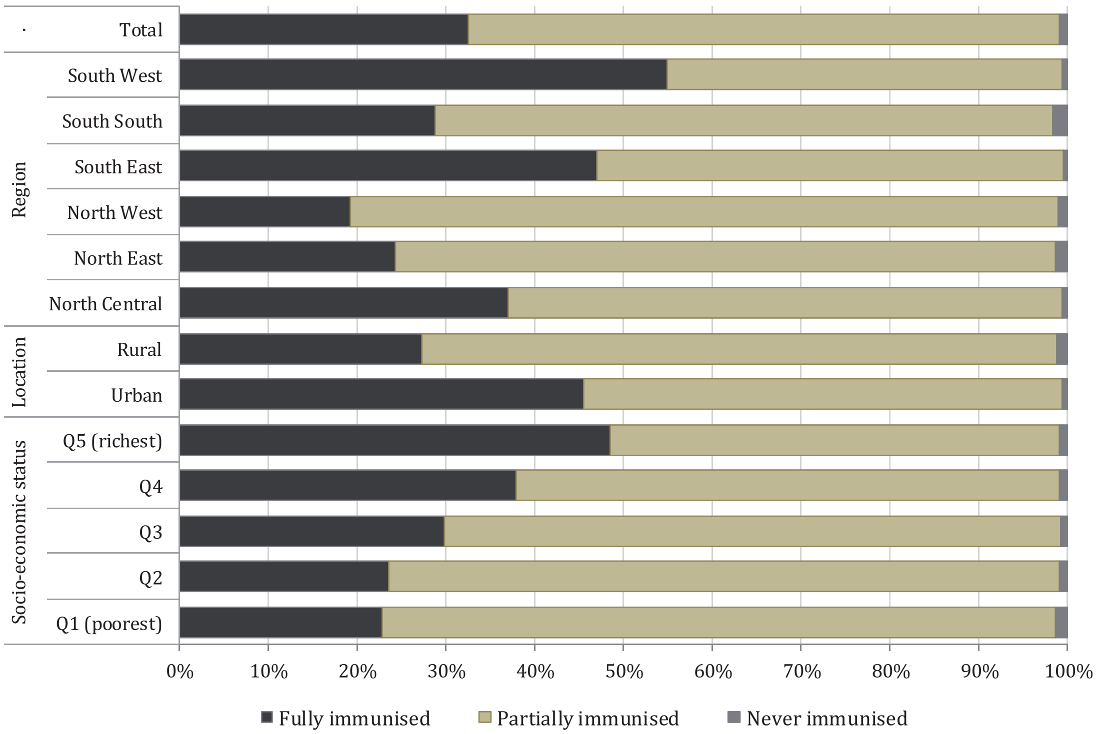

Figure 2. Distribution of immunization coverage for children (12–59 months) in Nigeria, 2006.

immunization coverage varied between regions and household SES. Close to half of the children in the richest households (Q_5) compared with about 23% in the poorest quintile (Q_1) are fully immunized. Full immunization coverage is also higher for urban children (46%) compared with rural children (27%). South West region has the highest (55%) full immunization coverage rate and the smallest partial immunization coverage rate while North West region has the least (<20%) full immunization coverage rate and the highest partial immunization coverage rate.

Concentration indices for fully immunized children shown in Table 1 confirm the distribution shown in Figure 2. Many richer children are fully immunized compared with poorer children. The relationship is statistically significant at conventional levels. For instance, the indirectly standardized concentration index based on Erreygers' normalization (E_C) was significantly estimated at 0.221 for all the children. Pro-rich inequality is consistent across all the geopolitical zones, and in rural and urban areas; full immunization is concentrated among richer households than poorer households.

However, the picture is different with partial immunization coverage (Table 2). The concentration indices are consistently negative and statistically significant at the 1% level; partial immunization is concentrated among poorer children than richer children ($E_C = -0.217$). The relationship is also similar for the geo-political zones and rural/urban locations.

Although never immunized children are concentrated among the poor (Table 3), the results are not statistically significant even at the 10% level. This is not surprising as the proportion of children aged 12–59 months that have never received an immunization is about 1% (Figure 1). However, a few geo-political zones (North West and South West) record significant concentration of never immunized children among the poor (Table 3).

Using the prop-poor curves that emanate from the concentration curves (Figure 3), the same conclusions are reached; full immunization coverage is concentrated among the rich because the curves (in panel A) and the associated confidence intervals are above the line of equality, partial immunization coverage is concentrated among the poor because the curves in panel (b) are above the line of equality while never immunized children show no statistically significant difference between SES.

The significant contributory factors to disparities in immunization coverage based on the results of the decomposition analysis (Table 4) include age of the child, location, literacy of the mother, SES and geopolitical zones fixed effects. The residual is significant for only those that are never immunized.

Based on the decomposition results (Figure 4), the significant factors that increase the concentration of fully immunized children among the rich include mother's literacy, living in the rural area, SES and geopolitical location. These same factors account for the significant concentration of the partially immunized children among the poor. For the never immunized, although the concentration index is not statistically significant at conventional levels, the factors that explain the disparities in coverage include mother's literacy, rural location and the residual (i.e. unexplained factors). Mainly mother's literacy, SES and geopolitical location explain the concentration of immunization intensity among the rich. Although not shown, the decomposition results are not sensitive to the exclusion of MMR antigen and vitamin A from the analyses.

Discussion

Paediatric immunization is regarded as one of the important health interventions in modern times as it contributes to substantial reductions in child deaths globally (Diekema and The Committee on Bioethics 2005; Bhutta *et al.* 2013). A disease like smallpox for example has been eliminated with the use of vaccines while others like polio and measles have been reduced substantially in developed countries. In fact, very recently, polio has been eradicated in Nigeria (Etsano *et al.* 2015). However, many developing countries still face

Table 1. Concentration indices for fully immunizd children (12–59 months) in Nigeria, 2006

	Unstandardized concentration index	Indirectly standardized concentration index	W_C	E_C
Geopolitical zone				
North Central	0.075** (0.0246)	0.083** (0.0269)	0.125** (0.0408)	0.113** (0.0366)
North East	0.099* (0.0422)	0.111* (0.0498)	0.141* (0.0632)	0.094* (0.0424)
North West	0.127** (0.0360)	0.153** (0.0420)	0.182** (0.0501)	0.099** (0.0272)
South East	0.132** (0.0218)	0.142** (0.0232)	0.253** (0.0415)	0.249** (0.0409)
South South	0.095** (0.0406)	0.108** (0.0455)	0.146** (0.0614)	0.112** (0.0471)
South West	0.049* (0.0196)	0.051* (0.0207)	0.106* (0.0431)	0.106* (0.0430)
Location				
Rural	0.109** (0.0166)	0.125** (0.0188)	0.165** (0.0249)	0.121** (0.0183)
Urban	0.110** (0.0188)	0.118** (0.0204)	0.205** (0.0354)	0.201** (0.0346)
Overall	0.168** (0.0131)	0.187** (0.0146)	0.265** (0.0207)	0.221** (0.0172)

Notes: asymptotic SEs in parenthesis; W_C, indirectly standardized concentration index based on Wagstaff's normalization; E_C, indirectly standardized concentration index based on Erreygers' normalization; *, ** statistically significant at 5 and 1% levels, respectively.

Table 2. Concentration indices for partially immunized children (12–59 months) in Nigeria, 2006

	Unstandardized concentration index	Indirectly standardized concentration index	W_C	E_C
North Central	−0.048** (0.0146)	−0.063** (0.0188)	−0.121** (0.0366)	−0.121** (0.0365)
North East	−0.033* (0.0135)	−0.039* (0.0168)	−0.100* (0.0426)	−0.095* (0.0407)
North West	−0.027** (0.0098)	−0.033** (0.0118)	−0.097** (0.0347)	−0.087** (0.0312)
South East	−0.119** (0.0213)	−0.162** (0.0299)	−0.265** (0.0488)	−0.251** (0.0463)
South South	−0.041* (0.0168)	−0.053* (0.0211)	−0.119* (0.0475)	−0.117* (0.0469)
South West	−0.055* (0.0241)	−0.080* (0.0351)	−0.116* (0.0506)	−0.098* (0.0431)
Rural	−0.041** (0.0064)	−0.052** (0.0079)	−0.123** (0.0187)	−0.120** (0.0183)
Urban	−0.091** (0.0153)	−0.122** (0.0207)	−0.205** (0.0346)	−0.197** (0.0333)
Overall	−0.081** (0.0064)	−0.103** (0.0082)	−0.217** (0.0174)	−0.217** (0.0173)

Notes: asymptotic SEs in parenthesis; W_C, indirectly standardized concentration index based on Wagstaff's normalization; EC, indirectly standardized concentration index based on Erreygers' normalization; *, ** statistically significant at 5 and 1% levels, respectively.

Table 3. Concentration indices for never immunized children (12–59 months) in Nigeria, 2006

	Unstandardized concentration index	Indirectly standardized concentration index	W_C	E_C
North Central	0.348 (0.2479)	0.012 (0.0149)	0.015 (0.0180)	0.009 (0.0104)
North East	0.019 (0.1198)	0.001 (0.0084)	0.002 (0.0103)	0.001 (0.0061)
North West	−0.276* (0.1219)	−0.016* (0.0081)	−0.020* (0.0099)	−0.012* (0.0058)
South East	0.140 (0.2091)	0.003 (0.0063)	0.004 (0.0077)	0.002 (0.0044)
South South	0.085 (0.1287)	0.007 (0.0119)	0.009 (0.0145)	0.005 (0.0088)
South West	−0.421** (0.1196)	−0.011** (0.0041)	−0.014** (0.0050)	−0.008** (0.0029)
Rural	−0.020 (0.0849)	−0.002 (0.0051)	−0.002 (0.0063)	−0.001 (0.0037)
Urban	−0.182 (0.1786)	−0.006 (0.0045)	−0.007 (0.0055)	−0.004 (0.0032)
Overall	−0.107 (0.0786)	−0.006 (0.0040)	−0.007 (0.0049)	−0.004 (0.0028)

Notes: asymptotic SEs in parenthesis; W_C, indirectly standardized concentration index based on Wagstaff's normalization; EC, indirectly standardized concentration index based on Erreygers' normalization; *, ** statistically significant at 5 and 1% levels, respectively.

a high burden of diseases and deaths from vaccine preventable illnesses. This is more so in countries in sub-Saharan Africa.

Using nationally representative data from Nigeria, this article reports that the extent of immunization coverage among children aged between 12 and 59 months varies substantially in Nigeria between regions and between socio-economic groups. Only about a third of children aged 12–59 months are fully immunized. The coverage of full immunization is also consistently higher among the rich, those in urban areas and those in wealthy geopolitical zones in the country. More than 60% of children are partially immunized with a higher prevalence among children coming from poorer households and those from rural locations. Although the proportion of children that have never been immunized is very small (1%), this is concentrated among the poor than among the rich. Data from the USA during the 1990s, for instance, indicated that >30% of children are not appropriately immunized before age 24 months (Lieu *et al.* 1994). It is not surprising therefore that Nigeria records over 60% children that have not received all the necessary immunization. In general, low uptake of immunization services is attributable to both demand- and supply-side factors including poverty (monetary and non-monetary), competing family priorities, perceived benefits from the health service, acceptability of services, problems with the outreach

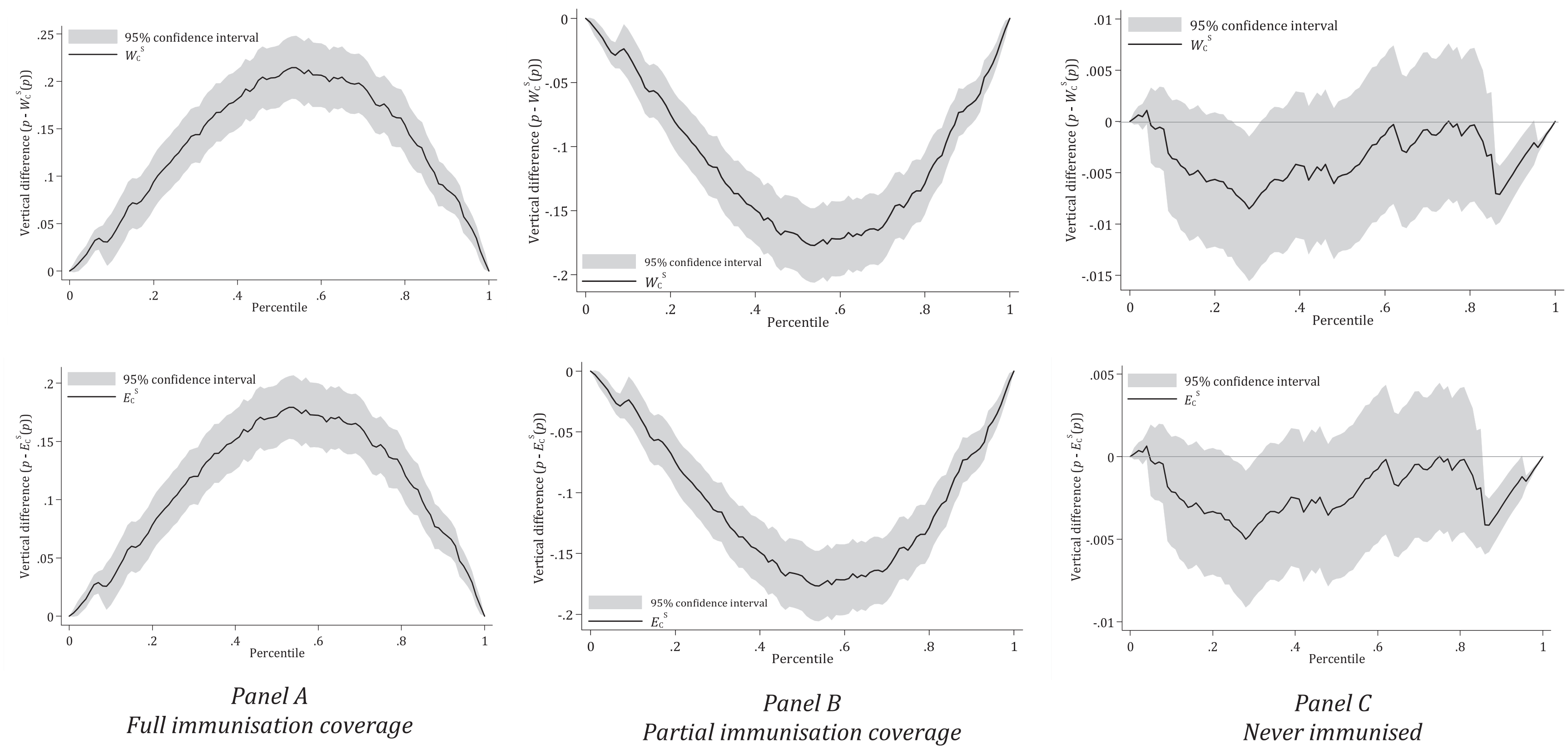

Figure 3. Pro-poor curves for immunization coverage for children (12–59 months) in Nigeria, 2006. W_C^S (E_C^S) represents Wagstaff's (Erreygers') normalization.

Table 4. Decomposition of concentration index for immunization coverage among children (12–59 months) in Nigeria, 2006

	Concentration indices	Fully immunized		Partially immunized		Never immunized		Immunization intensity	
	Elasticity	Contribution	Elasticity	Contribution	Elasticity	Contribution	Elasticity	Contribution	
Age	−0.006*** (0.0020)	0.370** (0.1837)	−0.002 (0.0014)	−0.171* (0.0917)	0.001 (0.0007)	−0.752 (1.2515)	0.004 (0.0079)	0.159*** (0.0568)	−0.001* (0.0005)
Age squared	−0.010*** (0.0035)	−0.051 (0.1064)	0.0005 (0.0011)	0.022 (0.0531)	−0.0002 (0.0006)	0.189 (0.7397)	−0.002 (0.0079)	−0.039 (0.0324)	0.0004 (0.0004)
Male	0.003 (0.0053)	−0.027* (0.0146)	−0.0001 (0.0002)	0.012 (0.0073)	0.00004 (0.0001)	0.079 (0.1028)	0.0003 (0.0007)	−0.002 (0.0044)	−0.00001 (0.0000)
Rural	−0.180*** (0.0083)	−0.165*** (0.0447)	0.030*** (0.0083)	0.075*** (0.0220)	−0.013*** (0.0041)	0.434** (0.2160)	−0.078** (0.0391)	−0.024 (0.0152)	0.004 (0.0028)
Literate mother	0.352*** (0.0078)	0.083*** (0.0179)	0.029*** (0.0064)	−0.038*** (0.0088)	−0.013*** (0.0031)	−0.223* (0.1339)	−0.078* (0.0471)	0.052*** (0.0064)	0.018*** (0.0023)
Q1	−0.800*** (0.0061)	−0.048*** (0.0157)	0.038*** (0.0124)	0.024*** (0.0077)	−0.020*** (0.0061)	−0.074 (0.1165)	0.059 (0.0924)	−0.029*** (0.0057)	0.023*** (0.0045)
Q2	−0.399*** (0.0134)	−0.056*** (0.0149)	0.022*** (0.0059)	0.030*** (0.0075)	−0.012*** (0.0030)	−0.173* (0.0942)	0.069* (0.0371)	−0.028*** (0.0054)	0.011*** (0.0022)
Q3	0.001 (0.0163)	−0.048*** (0.0144)	−0.00002 (0.0000)	0.026*** (0.0072)	0.00001 (0.0000)	−0.156* (0.0919)	−0.0001 (0.0001)	−0.014*** (0.0048)	−0.00001 (0.0000)
Q4	0.400*** (0.0145)	−0.029** (0.0135)	−0.012** (0.0054)	0.015** (0.0065)	0.006** (0.0026)	−0.068 (0.0890)	−0.027 (0.0357)	−0.006 (0.0043)	−0.002 (0.0017)
Fixed effects (geopolitical zones)	0.267*** (0.0027)	0.223*** (0.0324)	0.060*** (0.0087)	−0.108*** (0.0153)	−0.029*** (0.0041)	−0.091 (0.1204)	−0.024 (0.0323)	0.129*** (0.0125)	0.034*** (0.0033)
'Unexplained'			0.002 (0.0021)		−0.001 (0.0010)		−0.030** (0.0119)		0.001 (0.0007)
Total[a]			0.168***		−0.081***		−0.107		0.089

Notes: asymptotic SEs are shown in parenthesis in this column. Bootstrapped SEs (1000 resamples) are presented in parenthesis for other columns; *, **, *** statistically significant at 10, 5 and 1% levels, respectively.

services, availability of services etc. (Bates *et al.* 1994; Riportella-Muller *et al.* 1996).

Mother's literacy is identified as an important variable that contributes to the disparities in immunization coverage between socio-economic groups. Mother's education is very often argued to be associated with child health in many countries including in Nigeria (Odusanya *et al.* 2008; Antai 2009). The seminal article on this issue in Nigeria (Caldwell 1979) reports that educated mothers are able to enhance child survival through their level of education. This result is not surprising in the Nigerian context. In fact the levels of education between the socio-economic groups and between the geo-political zones reflect the nature of inequalities in immunization coverage; poorer geo-political zones have lower levels of immunization coverage and lower education attainment compared with their counterparts. Although there is a strong link between mother's education and child health indicators, there may not be a causal relationship between the two. Some studies even note that this correlation may be weak in sub-Saharan Africa (Hobcraft 1993; Desai and Alva 1998). However, the results from this article point to the very significant link that is also linked to other socio-economic variables. Therefore, addressing inequalities in immunization coverage in Nigeria will require, among other things, a strong focus on increasing educational levels of mothers especially by paying attention to the disparities in education attainment between geopolitical zones and socio-economic groups. Apart from using the formal education system, there may be a need to put in place a system that will inform and educate mothers on the basic importance of immunization for the health of their children and family.

Rural location is also an important factor that contributes to the disparities in child immunization coverage in Nigeria. DHSs in Nigeria have shown that immunization coverage is generally low for residents in rural areas when compared with those in urban areas (National Population Commission and Macro 2004). Elsewhere, other studies report low immunization coverage for those in rural communities (Dhadwal *et al.* 1997; Antai 2009; Banerjee *et al.* 2010). For example in Shimla hills, it was reported that 84% of urban children compared with 57% of rural children were vaccinated against polio (Dhadwal *et al.* 1997). In a study in rural India Banerjee *et al.* (2010) report that immunization coverage can be increased in rural communities by providing health services through immunization camps and giving incentives to mothers. However, while these are supply side factors, there may be other demand side factors that affect the uptake of immunization that need to be examined (Banerjee *et al.* 2010). Some of these factors can be summarized as acceptability factors that include culture and expectations that parents have from the health system (Thiede *et al.* 2007; McIntyre *et al.* 2009).

Geopolitical location in Nigeria is another major factor that contributes to the disparities in partial and full immunization coverage in the country. Data from the DHS show that immunization coverage varies by geopolitical zones and states in Nigeria (National Population Commission and Macro 2008); the northern geopolitical zones have much lower rates of immunization coverage than the states in the south. In fact in 2003, polio immunization was stifled in northern Nigeria due to distrust in the government and fears that vaccines are contaminated with anti-fertility agents (Renne 2006; Yahya 2007). This lends to the idea that parents prefer an 'error of omission' to an 'error of commission' (Fredrickson *et al.* 2004) as they are more inclined to accepting 'natural' risks than 'man-made' risks. When further attempts are made to immunize these children, they may view it as an unnecessary infringement on individual rights of freedom (Aspinwall 1997; Ross and Aspinwall 1997). Perhaps

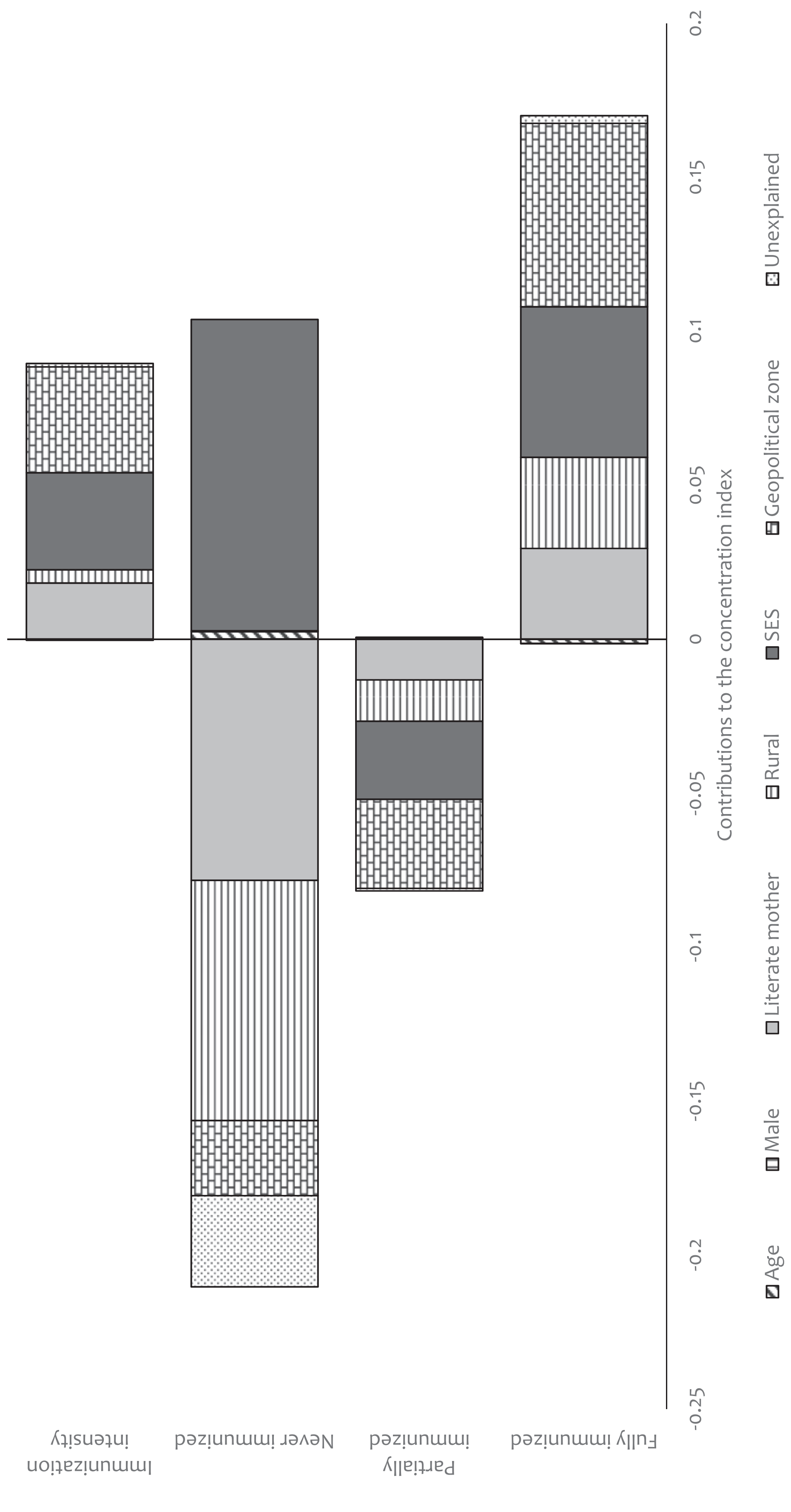

Figure 4. Decomposed contributions to concentration indices, Nigeria, 2006.

this is one of the issues that stands at the heart of the regional disparities in immunization coverage in the country.

The regional disparities found in Nigeria present an interesting picture that needs further investigation. A recent study of the drivers of these geographic disparities using only four states (two in the South and two in the North) concluded that supply-side factors such as the distribution of facilities with drug stock outs, short distance to facility and health personnel are not necessarily the issue because similar patterns exist between the states in most cases (Eboreime *et al.* 2015). Similar findings have been reported elsewhere (Stokes-Prindle *et al.* 2012). These results point to the need to as well look into demand-side issues and some other specific health systems issues such as acceptability of services and attitude of health workers. In terms of acceptability, there is an issue within the northern parts of the country with regards to vaccination being perceived negatively (Renne 2006; Yahya 2007; Ghinai *et al.* 2013). Findings from other studies show that in the context of Nigeria, the factors that account for the large partial immunization may result from, among other things, delayed immunization (Lieu *et al.* 1994), parental refusal (Diekema and The Committee on Bioethics 2005), or other access barriers to using health services including acceptability, availability and affordability (Thiede *et al.* 2007; McIntyre *et al.* 2009). Other factors include lack of knowledge about routine immunization, myths and rumours about immunization, and limited immunization campaigns (Babalola, 2011).

A variable that is very much correlated with rural/urban location and geopolitical zones in Nigeria is SES. In this article, it emerged that full vaccination is more prevalent among the rich than among the poor while partial and non-immunization are more prevalent among the poor. Also, the decomposition analysis shows that SES 'increases' the concentration of full immunization coverage among the rich and partial immunization among the poor. Elsewhere, higher immunization rates are associated with higher SES (Topuzoglu *et al.* 2005). This result is not surprising because it has been reported as the so-called health gradient in health studies (Adler *et al.* 1994; Deaton 2002; Ichoku *et al.* 2011). SES thus remains an important policy lever that governments can use to address a wide range of issues.

Among those that have never been immunized, 'unexplained factors' came up very significant. This result has been confirmed in a quasi-qualitative study in northern Nigeria where a 'significant number (16.6%) of the mothers whose children had not received any vaccination failed to articulate specific reasons for the lack of immunization' (Babalola 2011: 277). This also raises several questions about the acceptability of immunization services as well. One study that examined reasons why certain children receive no immunizations was conducted in Bath District in the UK. In that study, it emerged that the homoeopathy and religion are key reasons why certain children receive no immunizations (Simpson *et al.* 1995). These reasons particularly that of religion may be one of the reasons for the small number of children that never get immunized in Nigeria. In Nigeria, the regional disparities in non-immunization is also attributed to ideational and demand side factors including asymmetric distribution of power within the household, mother's limited awareness of childhood immunization schedule and sources, lack of exposure to the media, place of residence, polygyny status of the mother etc. (Babalola 2011). In some cases, the mothers noted that they felt their children are not sick to need medication or that the efficacy of the vaccine is questionable (Babalola 2011). This geopolitical dynamics needs to be taken into account in Nigeria when discussing ways to address disparities in immunization coverage.

Most of the issues that account for disparities in immunization coverage can also be summarized and understood under the social determinants of health (SDH) framework (Commission on Social Determinants of Health 2008; Krech 2011). This has also come out in a study in sub-Saharan Africa within the context of explaining low childhood immunization coverage (Wiysonge *et al.* 2012). It means therefore that apart from ensuring that supply-side factors such as the provision of health services are taken care of, addressing the SDH will lead to significant improvements in immunization uptake and reduce disparities between regions and socio-economic groups. The SDH include 'the structural determinants and conditions of daily life responsible for a major part of health inequities between and within countries. They include the distribution of power, income, goods and services, and the circumstances of people's lives, such as their access to health care, schools and education; their conditions of work and leisure; and the state of their housing and environment' (World Health Organization 2009: 1). These require the collaborative actions of relevant sectors other than health. Some of these issues have been raised in this article.

In terms of policy, because Nigeria is among the top five countries with a large number of under-5 and neonatal deaths in the world (Liu *et al.* 2015), there is a need to address the significant inequalities in immunization coverage in the country. There is also a need to pay attention to the differences between geopolitical zones in addressing the issue of immunization coverage including inequalities in immunization coverage in Nigeria. One of the major issues that emerged from this study is that there is a need to increase the level of awareness of mothers, particularly those in the northern regions where disparities and poverty levels are high, and literacy levels are low. Also, although immunization practises have been designed and agreed to internationally, there is a need to pay attention to the local political economy (Yahya 2007) context where such immunizations will be administered. In the context of Nigeria, previous studies have highlighted domestic issues relating to trust in governments or religion as local issues that have stifled previous attempts to increase immunization coverage in the country, particularly in the northern parts. Although this article does not claim to have all the answers as to how to address these issues, it highlights the significant issues with a view to stimulating detailed academic and policy debate in terms of designing policies to accelerate immunization coverage and close the gaps between geopolitical zones. The article thus notes that addressing the significant inequalities in immunization coverage in Nigeria is beyond providing immunization services free of charge.

This study has some strengths and limitations. Immunization coverage was split into three mutually exclusive categories—fully immunized, partially immunized and never immunized. This categorization is important because the 'reasons for non-immunization generally differ from those advanced for partial immunization' (Babalola 2011: 276). Therefore analysis of inequalities in immunization coverage should take this distinction into account. Further, the intensity of immunization was included. This is useful to uncover the factors that are associated with the receipt of more immunizations. This latter categorization provides richer information than either of the three mutually exclusive groups. Also, this article does not just assess which socio-economic group enjoys more immunization coverage but goes further to show factors that explain the disparities in immunization coverage for fully immunized, partially immunized, never immunized children and the intensity of immunization. This further analysis is useful from a policy perspective of addressing the challenges with low immunization coverage and for eliminating vaccine preventable deaths in the country.

Data limitation is one challenge of the study. The CWIQ dataset relies on self-report. This may lead to differences in coverage indicators when compared with other data sources as some mothers or caregivers may not be able to differentiate between vaccine types. However, the pattern of immunization coverage, which is relevant for inequality analysis, as reported in the article follows a priori expectations with poorer coverage reported in the northern regions compared with the southern regions. Further, the CWIQ dataset does not contain information on certain important variables such as religion and expenditure (or income). However, because of some level of correlation between religion and the geopolitical zones for instance (Ojo and Lateju 2010), the effect of religion may be captured by the inclusion of the geopolitical zones. The absence of expenditure data led to the construction of an index of SES using household assets and other socio-economic variables. Assessing the distribution of this index and that of per capita expenditure from another comparable nationally representative data shows some level of similarities in their distributions. Also, it is very likely that some children cannot be immunized because of underlying medical conditions including HIV for instance (Moss *et al.* 2003; Diekema and The Committee on Bioethics 2005). Although this issue has not been accounted for in the analysis, it is anticipated that only a very small proportion of children will have such underlying conditions. Thus, if anything, it will not affect the qualitative conclusions substantially. Another issue relates to the decomposition framework. A linear model was fitted to the data. However, as found elsewhere (Hosseinpoor *et al.* 2006), it is very unlikely that a non-linear model will change the qualitative conclusions significantly. Further, the article acknowledges the changes in the immunization landscape in Nigeria over the past decades. However, this has not been discussed in depth because it is unlikely to have substantial effect on the conclusion of inequality and the drivers of inequality as found in the article.

Conclusion

Over the past decades, there have been calls for countries to reduce child mortality rate substantially (Black *et al.* 2003; Liu *et al.* 2015). Although some countries have made substantial progress, many countries in sub-Saharan Africa still face high child mortality rates compared with other parts of the world (World Health Organization 2014; Liu *et al.* 2015). This is also the case in Nigeria. The importance of immunization in reducing child morbidity and mortality has long been recognized. In this regard, it is important to ensure an improvement in immunization coverage and to understand underlying factors that affect poor uptake and disparities in immunization coverage in countries. In Nigeria, large disparities have been reported in immunization coverage among children. Apart from addressing supply-side issues, the article notes the importance of addressing the broader SDH, including mothers' education level and acceptability issues, in improving immunization coverage and in reducing the significant disparities in immunization coverage in the country. These should pay attention to the disparities between geopolitical zones. Also, in order to increase acceptability and compliance, there is a need to pay attention to local context in adapting international recommendations. Any policy that addresses these issues will likely improve immunization coverage and put Nigeria on the road to sustainable development.

Acknowledgements

The authors acknowledge the comments and feedback received from researchers at the Centre for Health Economics and Development (CHECOD) in Nigeria. The views expressed are those of the authors. The usual disclaimer applies.

Funding

The lead author was awarded a Claude Leon Merit Award for young lecturers. This article was supported by this award from the Claude Leon Foundation.

Conflict of interest statement. None declared.

Notes

1. It is not possible to assess full immunization coverage on a sample of children who, technically speaking, are expected to be receiving vaccination doses. As a result, our analysis was based on the subsample of children aged 12–59 months.
2. Technically speaking, these are six vaccines (measles, BCG, DPT, OPV, yellow fever and MMR) and vitamin A (which is not a vaccine *per se*). However, we have retained the term 12 vaccines throughout which should be interpreted accordingly. Further, the MMR antigen is not available at the public sector. Although the results presented in this article are based mainly on the expanded list that includes MMR and vitamin A, sensitivity analysis shows that the results were not sensitive to the exclusion of these two.
3. These variables include: household head holding a formal employment; household head completing at least secondary education; household owning electric iron, refrigerator, television set, mobile phone, mattress or bed, radio, watch or clock, modern stove, vehicle or car, electric fan, video cassette recorder and furniture; roofing material of the house; wall material of house; clean source of fuel for lighting and cooking; use of a clean source of drinking water; and availability of public or private source of electricity (mains).
4. The immunization variables refer to the three mutually exclusive categories and the fourth category that measures the proportion of vaccinations received for children aged 12–59 months.

References

Adler NE, Boyce T, Chesney MA *et al*. 1994. Socioeconomic status and health: the challenge of the gradient. *American Psychologist* **49**: 15–24.

Antai D. 2009. Inequitable childhood immunization uptake in Nigeria: a multilevel analysis of individual and contextual determinants. *BMC Infectious Diseases* **9**: e181.

Aspinwall TJ. 1997. Religious exemption to childhood immunization statutes: reaching for a more optimal balance between religious freedom and public health. *Loyola University Chicago Law Journal* **29**: 109–40.

Ataguba JE, Akazili J, McIntyre D. 2011. Socioeconomic-related health inequality in South Africa: evidence from General Household Surveys. *International Journal for Equity in Health* **b**: 48.

Babalola S. 2011. Maternal reasons for non-immunisation and partial immunisation in northern Nigeria. *Journal of Paediatrics and Child Health* **47**: 276–81.

Banerjee AV, Duflo E, Glennerster R, Kothari D. 2010. Improving immunisation coverage in rural India: clustered randomised controlled evaluation of immunisation campaigns with and without incentives. *BMJ* **340**: c2220.

Bates AS, Fitzgerald JF, Dittus RS, Wolinsky FD. 1994. Risk factors for underimmunization in poor urban infants. *JAMA: The Journal of the American Medical Association* **272**: 1105–10.

Bhutta ZA, Das JK, Walker N *et al*. 2013. Interventions to address deaths from childhood pneumonia and diarrhoea equitably: what works and at what cost? *The Lancet* **381**: 1417–29.

Black RE, Morris SS, Bryce J. 2003. Where and why are 10 million children dying every year? *The Lancet* **361**: 2226–34.

Brockerhoff M, Hewett P. 2000. Inequality of child mortality among ethnic groups in sub-Saharan Africa. *Bulletin of the World Health Organization* **78**: 30–41.

Bryce J, Boschi-Pinto C, Shibuya K, Black RE. 2005. WHO estimates of the causes of death in children. *The Lancet* **365**: 1147–52.

Caldwell JC. 1979. Education as a factor in mortality decline an examination of Nigerian data. *Population Studies* **33**: 395–413.

Cameron AC, Trivedi PK. (2009). *Microeconometrics Using Stata*, Texas, USA: Stata Press.

Chuma J, Molyneux C. 2009. Estimating inequalities in ownership of insecticide treated nets: does the choice of socio-economic status measure matter? *Health Policy and Planning* **24**: 83–93.

Commission on Social Determinants of Health. 2008. Closing the gap in a generation: health equity through action on the social determinants of health. *Final Report of the Commission on Social Determinants of Health*. Geneva: World Health Organization.

Deaton A. 2002. Policy implications of the gradient of health and wealth. *Health Affairs* **21**: 13–30.

Desai S, Alva S. 1998. Maternal education and child health: is there a strong causal relationship? *Demography* **35**: 71–81.

Dhadwal D, Sood R, Gupta AK, *et al*. 1997. Immunization coverage among urban and rural children in the Shimla hills. *The Journal of Communicable Diseases* **29**: 127–30.

Diekema DS; The Committee on Bioethics. 2005. Responding to parental refusals of immunization of children. *Pediatrics* **115**: 1428–31.

Doorslaer E, Koolman X. 2004. Explaining the differences in income-related health inequalities across European countries. *Health Economics* **13**: 609–28.

Duclos JY, Araar A. (2006). *Poverty and Equity: Measurement, Policy, and Estimation with DAD*. Berlin and Ottawa: Springer and IDRC.

Eboreime E, Abimbola S, Bozzani F. 2015. Access to routine immunization: a comparative analysis of supply-side disparities between northern and southern Nigeria. *PLoS One* **10**: e0144876.

Efron B. 1987. Better bootstrap confidence intervals. *Journal of the American Statistical Association* **82**: 171–85.

Efron B, Tibshirani R. 1986. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. *Statistical Science* **1**: 54–75.

Erreygers G. 2009a. Correcting the concentration index. *Journal of Health Economics* **28**: 504–15.

Erreygers G. 2009b. Correcting the concentration index: a reply to Wagstaff. *Journal of Health Economics* **28**: 521–4.

Etsano A, Gunnala R, Shuaib F *et al*. 2015. Progress toward poliomyelitis eradication -Nigeria, January 2014-July 2015. *MMWR: Morbidity and Mortality Weekly Report* **64**: 878–82.

Federal Ministry of Health. 2013. *National Routine Immunization Strategic Plan 2013-2015*, Abuja: National Primary Health Care Development Agency.

Filmer D, Pritchett L. 2001. Estimating wealth effects without expenditure data-or tears: an application to educational enrollments in states of India. *Demography* **38**: 115–32.

Fredrickson DD, Davis TC, Arnould CL, *et al*. 2004. Childhood immunization refusal: provider and parent perceptions. *Family Medicine* **36**: 431–9.

Ghinai I, Willott C, Dadari I, Larson HJ. 2013. Listening to the rumours: what the northern Nigeria polio vaccine boycott can tell us ten years on. *Global Public Health* **8**: 1138–50.

Hobcraft J. 1993. Women's education, child welfare and child survival: a review of the evidence. *Health Transition Review* **3**: 159–75.

Hosseinpoor AR, Van Doorslaer E, Speybroeck N *et al*. 2006. Decomposing socioeconomic inequality in infant mortality in Iran. *International Journal of Epidemiology* **35**: 1211–9.

Ichoku HE. 2011. On the use of socioeconomic status indicators in the analysis of health inequalities and poverty in Africa. *Journal of International Development* **23**: 1004–12.

Ichoku HE, Fonta WM, Thiede M. 2011. Socioeconomic gradients in self-rated health: a developing country case study of Enugu State, Nigeria. *Economic Change and Restructuring* **44**: 179–202.

Jones G, Steketee RW, Black RE, Bhutta ZA, Morris SS. 2003. How many child deaths can we prevent this year? *The Lancet* **362**: 65–71.

Kakwani N, Wagstaff A, van Doorslaer E. 1997. Socioeconomic inequalities in health: measurement, computation, and statistical inference. *Journal of Econometrics* **77**: 87–103.

Krech R. 2011. Social determinants of health: practical solutions to deal with a well-recognized issue. *Bulletin of the World Health Organization* **89**: 703-703.

Lawn JE, Cousens S, Zupan J. 2005. 4 million neonatal deaths: When? Where? Why? *The Lancet* **365**: 891–900.

Lieu TA, Black SB, Ray P *et al*. 1994. Risk factors for delayed immunization among children in an HMO. *American Journal of Public Health* **84**: 1621–5.

Lim SS, Stein DB, Charrow A, Murray CJL. 2008. Tracking progress towards universal childhood immunisation and the impact of global initiatives: a systematic analysis of three-dose diphtheria, tetanus, and pertussis immunisation coverage. *The Lancet* **372**: 2031–46.

Liu L, Oza S, Hogan D *et al*. 2015. Global, regional, and national causes of child mortality in 2000–13, with projections to inform post-2015 priorities: an updated systematic analysis. *The Lancet* **385**: 430–40.

McIntyre D, Thiede M, Birch S. 2009. Access as a policy-relevant concept in low- and middle-income countries. *Health Policy, Economics and Law* **4**: 179–93.

Moss WJ, Clements CJ, Halsey NA. 2003. Immunization of children at risk of infection with human immunodeficiency virus. *Bulletin of the World Health Organization* **81**: 61–70.

National Bureau of Statistics. 2014. *Harmonized Nigeria Living Standard Survey 2009/10: Core Welfare Indicator Questionnaire Survey 2009 (part A)*. Abuja: National Bureau of Statistics.

National Population Commission & ICF International. 2014. *Nigeria Demographic and Health Survey 2013*. Abuja, Nigeria and Rockville, Maryland, USA: National Population Commission and ICF International.

National Population Commission & Macro, I. 2008. *Nigeria Demographic and Health Survey 2008*. Abuja, Nigeria: National Population Commission and ICF Macro.

National Population Commission & Macro, O. 2004. *Nigeria Demographic and Health Survey 2003*. Calverton, Maryland: National Population Commission and ORC Macro.

National Primary Healthcare Development Agency. 2009. *National Immunization Policy*. Abuja: National Primary Healthcare Development Agency.

Norheim OF, Jha P, Admasu K *et al*. 2015. Avoiding 40% of the premature deaths in each country, 2010–30: review of national mortality trends to help quantify the UN Sustainable Development Goal for health. *The Lancet* **385**: 239–52.

O'Donnell O, Van Doorslaer E, Wagstaff A, Lindelow M. (2008). *Analyzing Health Equity Using Household Survey Data: A Guide to Techniques and Their Implementation*. Washington DC: World Bank Publications.

Odusanya OO, Alufohai EF, Meurice FP, Ahonkhai VI. 2008. Determinants of vaccination coverage in rural Nigeria. *BMC Public Health* **8**: 381.

Ojo MA, Lateju FT. 2010. Christian–Muslim conflicts and interfaith bridge-building efforts in Nigeria. *The Review of Faith and International Affairs* **8**: 31–8.

Phiri J, Ataguba JE. 2014. Inequalities in public health care delivery in Zambia. *International Journal for Equity in Health* **13**: 24.

Renne E. 2006. Perspectives on polio and immunization in Northern Nigeria. *Social Science and Medicine* **63**: 1857–69.

Riportella-Muller R, Selby-Harrington ML, Richardson LA *et al*. 1996. Barriers to the use of preventive health care services for children. *Public Health Reports* **111**: 71.

Ross LF, Aspinwall TJ. 1997. Religious exemptions to the immunization statutes: balancing public health and religious freedom. *The Journal of Law, Medicine and Ethics* **25**: 202–9.

Simpson N, Lenton S, Randall R. 1995. Parental refusal to have children immunised: extent and reasons. *Bmj* **310**: 225–7.

StataCorp. 2011. *Stata: Release 12 - Statistical Software*. College Station, Texas: StataCorp LP.

Stokes-Prindle C, Wonodi C, Aina M *et al*. 2012. *Landscape Analysis of Routine Immunization in Nigeria: Identifying Barriers and Prioritizing Interventions*. Baltimore: International Vaccine Access Center & Johns Hopkins Bloomberg School of Public Health.

Thiede M, Akweongo P, McIntyre D. (2007). Exploring the dimensions of access. In*:* McIntyre D, Mooney G (eds). *The Economics of Health Equity*. UK: Cambridge University Press.

Topuzoglu A, Ozaydın GAN, Cali S, *et al*. 2005. Assessment of sociodemographic factors and socio-economic status affecting the coverage of compulsory and private immunization services in Istanbul, Turkey. *Public Health* **119**: 862–9.

UNICEF. 2007. *The State of the World's Children 2008*. New York: United Nations Children's Fund (UNICEF).

UNICEF. 2015. *Levels and Trends in Child Mortality: Report 2015*. New York: United Nations Children's Fund.

United Nations. 2001. Road map towards the implementation of the United Nations Millennium Declaration: report of the Secretary-General. *General Assembly: Fifty-Sixth Session*. New York: United Nations.

Vyas S, Kumaranayake L. 2006. Constructing socio-economic status indices: how to use principal components analysis. *Health Policy and Planning* **21**: 459–68.

Wagstaff A. 2005. The bounds of the concentration index when the variable of interest is binary, with an application to immunization inequality. *Health Economics* **14**: 429–32.

Wagstaff A. 2009. Correcting the concentration index: a comment. *Journal of Health Economics* **28**: 516–20.

Wagstaff A, Paci P, van Doorslaer E. 1991. On the measurement of inequalities in health. *Social Science and Medicine* **33**: 545–57.

Wagstaff A, van Doorslaer E, Watanabe N. 2003. On decomposing the causes of health sector inequalities with an application to malnutrition inequalities in Vietnam. *Journal of Econometrics* **112**: 207–23.

Wagstaff A, Watanabe N. 2003. What difference does the choice of SES make in health inequality measurement? *Health Economics* **12**: 885–90.

Wamani H, Tylleskär T, Åstrøm AN, Tumwine JK, Peterson S. 2004. Mothers' education but not fathers' education, household assets or land ownership is the best predictor of child health inequalities in rural Uganda. *International Journal for Equity in Health* **3**: 9.

Wiysonge CS, Uthman OA, Ndumbe PM, Hussey GD. 2012. Individual and contextual factors associated with low childhood immunisation coverage in sub-Saharan Africa: a multilevel analysis. *PLoS One* **7**: e37905.

World Health Organization. 2009. *World Health Assembly 62.9. Commission on Social Determinants of Health*. http://apps.who.int/gb/ebwha/pdf_files/A62/A62_9-en.pdf. Geneva: World Health Organization.

World Health Organization. 2014. *World Health Statistics 2014*. Geneva: World Health Organization.

Yahya M. 2007. Polio vaccines—"no thank you!" barriers to polio eradication in Northern Nigeria. *African Affairs* **106**: 185–204.