# Do places matter? A comparative multilevel analysis of community effects on Child Immunization in sub-Saharan Africa

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## INTRODUCTION

Despite improved interventions, increased overall resources in the health sector, and a history of success, full vaccination coverage remains low and irregular in her progression in sub-Saharan Africa (SSA) (Bodart et al., 2001; Bryce et al., 2005; Sia et al., 2007; WHO, 2007). There are large persistent disparities in child immunization coverage between and within countries (Arevshatian et al., 2007; WHO, 2007). For example, while a new national health survey finds that immunization rates in Benin are decreasing, immunization coverage of children ages 12 to 23 months increased markedly since 2001 in Mali (MEASURE DHS, 2007: http://www.measuredhs.com/pr1/archives.cfm?year=2008).

Yet immunization coverage is seen as an important instrument in achieving the UN's Millennium Development Goal of reducing under-5 mortality by two-thirds between 1990 and 2015 (UNDP, 2007). Numerous studies have demonstrated the considerable importance of preventive health measures such as vaccination in reducing child mortality, morbidity, and disability (Kuate Defo, 1994; Jones et al., 2003; Fotso et al., 2007). Indeed, vaccines have significantly reduced or, in some areas, eliminated diseases such as smallpox (Kiros & White, 2004). The six diseases (measles, pertussis, diphtheria, tuberculosis, tetanus, poliomyelitis) of the expanded program of immunization (EPI) continue to seriously effect morbidity and mortality in SSA (Feachem & Jamison, 1991). Providing full immunization coverage to substantially reduce infant and child mortality is a high-priority national public health objective in many SSA countries.

Why do some countries consistently immunize children more effectively than others? Both practical and theoretical concerns motivate the question. Practically, there is little systematic evidence about what policies and vaccination strategies expand immunization coverage (Gauri & Khaleghian, 2002).

Previous studies, using multilevel methods, suggested that variations in child immunization uptake typically remain after accounting for individual and household factors (Pebley et al., 1996). Recent years has witnessed a growing recognition of the importance of contextual influences on maternal and child health services utilization; in particular several studies have found significant effects of community level factors on child immunization (Pebley et al., 1996; Steele et al., 1996; Matthews & Diamond, 1997; Gauri & Khaleghian, 2002; Gaudin & Yazbeck, 2006; Sia et al., 2007). This thanks to the increasing availability of relatively reliable data, provide by the wave of Demographic and Health Surveys (DHS). Often community-level effects and individual-level effects run in the same direction.

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At the community level, previous research of the uptake of the child immunization have focused on the influence of health service characteristics (e.g. hospital availability, distance to facility), neglecting for example the cultural factors (Glei et al., 2003; Minh Thang et al., 2006; Anand & Barnighausen, 2007; Datar et al., 2007). Variation in immunization rate was also usually framed by contextual issues relating to funding and organization of health care or social and cultural issues (Say & Raine, 2007). Some studies have examined the effects of other characteristics of the community, including the influence of levels of community economic development, and the global policy environment and contact with international agencies (Gauri & Khaleghian, 2002), community level education (Parashar, 2005), women's paid labor force participation (DeRose & Amen, 2006), health worker density and human resources (Anand & Barnighausen, 2007), on immunization rate coverage.

However, in SSA, scientific knowledge on how community-level factors influence health care utilization, including immunization for children under 5, remains fragmentary.(Gage et al., 1997; Rajaratnama et al., 2006; Say & Raine, 2007; Sia et al., 2007). Furthermore, the other main weakness of the existing studies is their limited focus (a single country or region within a country) and the heterogeneity in the definitions adopted (Rajaratnama et al., 2006). There have been very few comparative studies of the influence of the community-level factors on child immunization coverage, in particular on sub-Saharan Africa (Gage et al., 1997). The studies taking of account several countries would make it possible to better emphasize the diversity of the situations, to release the real tendencies independently of the local and national contexts, and better to perhaps specify the determinants of child immunization coverage.

Based on the wealth of data from the latest phase of DHS, our main objective is to deepen understanding of the effect of contextual factors on child immunization coverage in Africa, beyond individual-level factors. In others words, we took a holistic view of contextual influences on child health care utilization (Gauri & Khaleghian, 2002; Stephenson et al., 2006), to examine how community characteristics (such as ethnic fractionalization, level of educational development, type of place of residence; access to health service, economic development) may influence the likelihood of complete child immunization in different contexts in SSA.

On a comparative basis, the empirical analysis will relate systematically to the whole of the country having recently collected Community information at the time of the DHS in SSA. They are: Benin, Chad, Gabon, Guinea, Mali, Mauritania and Niger. This research contributes to literature on child health by assessing effects of community attributes across a wide range of cultural and economic settings.

## DATA AND METHODS

### *DATA*

We use data from the latest round of Demographic Health Surveys for all countries in sub-Saharan Africa that include community-level information. These are: Benin (2001), Chad (2004), Gabon (2000), Guinea (1999), Mali (2001), Mauritania (2000/01) and Niger (1998). The DHS have comparable information on community and household characteristics as well as on immunization status and health of women aged 15-49 years and their children born within three to five years before the survey date, known to be of good quality. The analysis of immunization coverage focuses on the children of 12-23 months of age during the Survey.

This age group is selected because full immunization is recommended for all children by age of one year. According to World Health Organization (WHO) guidelines (WHO, 1984), the recommended immunization schedule is: BCG immunization (against tuberculosis) at birth; three doses of DPT (diphtheria, pertussis, tetanus) vaccine and three doses of oral polio vaccine at 6, 10, and 14 weeks after birth; and measles immunization at nine months after birth. The selected countries exhibit quite different socioeconomic and demographic profiles.

*Dependent variable*
The dependent variable in our analysis is whether a child received full immunization or not. Thus it is a binary variable. Children classified as fully immunized have obtained all eight recommended vaccinations at the time of survey.

*Explanatory Variables*
In accordance with the existing literature on child health care choices, we include a set of several individual and household characteristics as well as cluster characteristics that might have an effect on the uptake child immunization.

<u>Child/family-level covariates</u>: Age of the child, Year of birth, Sex of child, Preceding birth interval, Immunized from last immunization campaign, Mother's age at child birth, Antenatal care, Place of delivery, Delivery assistance, Household wealth Index, and Maternal education.

<u>Community-level covariates</u>: Type of place of residence; Access to health services (Distance to nearest hospital); Economic development; Education (Proportion of women who are literate); Ethnic fractionalization.

*STATISTICAL ANALYSIS*
Because of the multilevel nature of our question as well as the clustering of children within families/women and communities, and because the relevant outcome is binary responses, for regression analyses, we used a three-level logistic regression model. Below we describe briefly the model.

Let $Y_{ijk}$ be a binary response for the $i^{th}$ child in the $j^{th}$ family and nested within the $k^{th}$ community (cluster), where $Y_{ijk}=1$ if the child is fully immunized and $Y_{ijk}=0$ if the child is not. Let $\pi_{ijk}$ denote the response probability of the $i^{th}$ child of the $j^{th}$ family in the $k^{th}$ community being fully immunized (i.e., $\pi_{ijk}=\text{Prob}(Y_{ijk}=1)$). Then model can be written by the following equations , using multilevel modeling notation from Snijders and Bosker (1999):

$$\begin{cases} Y_{ijk}=\pi_{ijk}+\varepsilon_{ijk} & \text{(Eq. 1)} \\ \text{Logit}\ \pi_{ijk}=X_{ijk}\beta+\mu_{jk}+\nu_k & \text{(Eq. 2)} \end{cases}$$

In this system of equations, $\beta$ is a vector of regression coefficients corresponding to the effect of fixed covariates $X_{ijk}$ (which represent observed characteristics of the child, the family and community); $\varepsilon_{ijk}$ is a child-level error term distributed as Bernoulli; $\mu_{jk} \sim N(0,\sigma^2_\mu)$ is a family level error term, and $\nu_k \sim N(0,\sigma^2_\nu)$ is a community-level error term. This model is know as a random intercepts or variance components model as the intercept, or average probability of receiving full immunization, is assumed to vary randomly across households and communities. (Steele et al., 1996; Kiros & White, 2004). The random effects $\mu_{jk}$ and $\nu_k$

represent unobserved family and community factors shared between siblings and between children living in the same communities, respectively. Probability of immunization of children living in the same community (but not in the same family) are correlated because they share the random effect $\nu_k$. And probability of immunization of children living in the same family are correlated because they share the random effects $\mu_{jk}$ and $\nu_k$.

We present odds ratio coefficients for independent variables at both the individual, family and community levels while adjusting for random intercepts between communities. However, an advantage of using multilevel models is that we could examine how much of the variation in outcome variable was due to variations between family or communities and how much was due to variations within communities (i.e., between individuals).

The degree of resemblance between micro-units belonging to the same macro-unit can be expressed by the intraclass correlation coefficient (ICC). Values departing from zero point to greater similarity among children at that level of aggregation. The correlations between the probability of immunization among children in the same community and the same family are, respectively, given by (Pebley et al., 1996; Snijders & Bosker, 1999):

$\rho_\nu = \sigma_\nu^2/[\sigma_\nu^2 + \sigma_\mu^2 + \sigma_\varepsilon^2]$ and $\rho_\mu = (\sigma_\nu^2 + \sigma_\mu^2)/[\sigma_\nu^2 + \sigma_\mu^2 + \sigma_\varepsilon^2]$ (Eq. 3)

In other word, the ICC is the proportion of variance in the dependent variable that is due to grouping effects (Raudenbush & Bryk, 2002). A non-zero ICC indicates that the assumption of independent subjects is violated, and using a traditional regression model will lead to deceptive results. Acknowledgement of an ICC means acknowledgement of grouping effects, thus a hierarchical model is needed to represent the data. The individual level variance, $\sigma_\varepsilon^2$ is equal to $\pi^2/3$ (Snijders & Bosker, 1999). The total variability in individual probability of immunization can be partitioned into three components: (a) variance among children within families, (b) families within communities, and (c) communities. A high ICC indicates large geographic differences between community or family. High values of the ICC provide more justification for targeting interventions at the community-level (Schootman et al., 2007 p. 706).

In addition, an other important advantage is that the model also allows measurement of the proportion of the total community-level (respectively family-level) variance in the outcome variable that is explained by predictor variables (either at the individual-level, or at both individual-level and community-level together), relative to a model of the same form that has fewer or no predictor variables. It is calculated as: $[\sigma_0^2 - \sigma_n^2] / \sigma_0^2$ x100 (also called proportional change in variance), where $\sigma_0^2$ is the community-level (respectively family-level) variance of the initial model (with fewer or no predictors), and $\sigma_n^2$ is the community-level variance of the model with all the predictors. This approach allows calculation of the extent to which the clustering in the outcome variable at the community-level is explained by each set of predictor variables at the individual or community level (Merlo et al., 2006). Thus, reduction in ICC relative to unadjusted analysis was evidence for explaining geographic variation by the variables included in a multivariable model (Schootman et al., 2007).

Models are fitted using the MLwin software version 2.02 with Binominal, Penalised Quasi-Likelihood (PQL) and second-order linearization procedure, which provides least biased results when there are few level-1 (children) units per level-2 (family) unit (Rodriguez &

Goldman, 1995; Rasbash et al., 2000; Goldstein et al., 2002; Browne et al., 2005; Twisk, 2006), which is incorporated in the recently developed MLwiN version to obtain more accurate estimates.

*Modeling Strategy*
We fitted three models. Model I (the empty model) did not include any explanatory variables and only focused on decomposing the total fully immunization variance (VTotal) in its child ($\sigma_\varepsilon$) family ($\sigma_\mu$) and community ($\sigma_\nu$) components. From the empty model, we calculated the intracommunity and intrafamily correlations, respectively, without controlling for any predictor. Intracommunity is correlation across mothers within the same community, and Intrafamily correlation refer correlation across children for the same mother and within the same community. In model II we included only individual-level variables (child and family characteristics) as predictors. In the last model III we included the community characteristics in addition to the variables already included in model II.

## EXPECTED FINDINGS, CONCLUSION AND DISCUSSION

The objective of this study is to identify important family- and community-level factors that affect whether sub-Saharan Africa children are fully immunized.

We expect:

(1) ICC (family) greater than ICC (community). Likely, after controlling for the observed variables, the variance due to households will be higher than due to communities.

(2) Child immunization will be more prevalent in communities where proportion of women's literate is at higher levels as well as in urban area.

(3) Ethnic fractionalization, defined as the probability that two individuals selected at random from a community will be from different ethnic groups, increases the chance to complete fully immunization.

Following tables are on going to build.

(1) Table x: Percent distribution of child by selected variables in the models
(2) Table xx: Percentage of children age 12-23 months who are immunized by type of vaccine, in 7 SSA countries.
(3) Table xxx: intracommunity and intrafamily correlations of proportion receiving full immunization.
(4) Table xxxx: Estimated odds ratios and t-values for multilevel logistic models of the probability of receiving a complete set of immunization among children's 12-23 months, by country.

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