Education is the antidote: Individual- and community-level effects of maternal education on child immunizations in Nigeria

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A R T I C L E   I N F O

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- Immunizations
- Vaccines
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- Spatial analysis
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A B S T R A C T

Nigeria is an interesting case study because it outperforms other lower middle-income countries in economic development, yet ranks among the lowest in the world in immunization coverage rates. Combining multi-level modeling with spatial data techniques, this study investigates the individual- and community-level factors that influence the likelihood that a child is fully immunized, underscoring the importance of maternal education for improving child health. Drawing on data from the Demographic and Health Surveys and the Global Administrative Areas database, the analysis pools data on children aged 12–24 months across 455 communities. The spatial analysis reveals substantial geographic gaps in immunization coverage across Nigeria, demonstrating that not everyone benefits from the purported benefits of economic growth. Results from the multi-level models indicate that women's education has a robust association with vaccinations at the individual level and at the community level, even net of a variety of other household and community characteristics. The education level of a child's own mother influences the likelihood of being immunized, but above and beyond that, living in a community in which many women are educated also influences that likelihood. This suggests that education has a protective effect on child health not only because more individual women are going to school, but also because everyone benefits from the education and empowerment of women in the community. As broad societal transformations take place, education may shape women's capacity to take advantage of better access to power and resources, resulting in a dispersion effect of expanded women's education on health.

1. Introduction

According to recent World Bank rankings of gross domestic product (GDP), Nigeria is the largest economy in Africa and the 21st largest economy in the world, putting it on par with countries like Australia and Poland (World Bank, 2016). Despite substantial overall economic growth over the last several decades, Nigeria has not experienced the broad-based improvements in wellbeing that typically correlate with higher GDP per capita. As Table 1 demonstrates, Nigeria outperforms other emerging market and developing countries in GDP per capita, yet lags behind its counterparts in health outcomes such as child immunizations, child mortality, and life expectancy. This makes Nigeria an interesting case study, given the conventional paradigm across the social sciences that economic growth is the most important mechanism for achieving better health and wellbeing (Brady et al., 2007).

This study focuses specifically on child immunizations, one of the most important public health interventions for preventing disease, disability, and death (UNICEF/WHO, 2017). Using geospatial analysis, we demonstrate the geographic disparities in vaccine uptake across Nigeria. This demonstrates that not everyone benefits from the purported benefits of economic growth. Then, using multilevel models, we investigate the individual- and community-level factors that influence the likelihood that a child is fully immunized, underscoring the importance of maternal education for improving child health. Country-level comparisons of women's education and literacy reveal important aggregate patterns across the world (e.g., Burroway, 2015; Smith et al., 2003), but they do not interrogate the distribution of women's education within a country. This is an important limitation since within-country variation can be substantial, especially in a country of Nigeria's size and population density. Despite the overall growth of the Nigerian economy, there is indeed much variation in living standards, poverty rates, educational attainment, and child health throughout the country (World Bank, 2014). At the same time, individual-level assessments of women's education reveal important findings about household processes (e.g., Hatt and Waters, 2006), but they neglect the fact that individuals are embedded in and greatly influenced by the larger social structures of which they are a part (Farmer, 2005). Multilevel modeling is a useful technique for overcoming these limitations, since it...
incorporates household characteristics as well as broader social norms into the analysis (Treas and Tai, 2012). By concentrating on one case, we are able to examine the meso-level (i.e., the community), which may help shed some light on why Nigeria defies the expectations of the economic growth paradigm.

Research on women's education proliferated after Caldwell's (1979) pioneering study in which he underscored the importance of maternal education for reducing child mortality in Nigeria. However, prior research on women's education in Nigeria typically concentrates on measuring education at the individual level (e.g., Adenike et al., 2017; Smith-Greenaway, 2013). What has largely been missing is an analysis that incorporates both the individual and contextual effects of women's education for improving child health. That is, does it matter whether a child's mother is educated, but beyond that, does it matter if a child lives in a community where many women are educated? As broad societal transformations take place, education may shape women's capacity to seek and take advantage of better access to power and resources, resulting in a “dispersion effect” of expanded women's education on child health (Parashar, 2005).

In sum, this study contributes to extant literature in several key ways. First, the spatial analysis reveals substantial geographic gaps in immunization coverage across Nigeria in a way that is not possible using traditional statistical techniques. Such information is integral to health professionals and policymakers in reallocating resources to reach more of the population and in targeting health interventions at communities with the greatest need. Second, the multilevel approach highlights the ways in which a child's community context shapes their chances of immunization. The findings show that the average education level of a community has a beneficial effect on child health, regardless of the education level of a child's own mother. This suggests that everyone, even children of uneducated mothers, benefit from the education of women in the community overall. Such a finding would be obscured by traditional regression models that do not account for nested data structures.

2. Immunizations in Nigeria

Nigeria launched the Expanded Programme on Immunization (EPI) in 1978, an initiative to provide routine immunizations to all children younger than 2 years old and to stop the spread of killer diseases. Core activities of the EPI include monitoring immunization schedules, monitoring immunization coverage and ensuring all districts are well covered, and disease surveillance. The Nigerian EPI reached the height of its success in the early 1990s, which was followed by a gradual decline in immunization coverage (Ophori et al., 2014). This decline mirrored the waning of global universal childhood immunization efforts during the same time period due to dwindling political will, inadequate funding, and low participation (Adenike et al., 2017). The government has since revitalized its EPI program and immunization rates in recent years are rising again (Gidado et al., 2014). Data from the four latest rounds of the Demographic and Health Surveys (DHS) in Nigeria illustrate this story. The percentage of children aged 12–24 months who are fully immunized declined from approximately 30% in 1990 to 6% in 2003. This percentage rose to 14% in 2008 and increased again to 24% in 2013 (author calculations based on age and number of vaccines received).

Despite the goals of the EPI, routine immunization coverage in Nigeria is among the lowest in the world (Adenike et al., 2017; Ophori et al., 2014; UNICEF/WHO, 2017). For example, a recent study across 40 districts finds that the median coverage for each vaccine dose is below 50% (Gunnala et al., 2016). Coverage of the third dose of diphtheria-pertussis-tetanus is the lowest of all vaccines, ranging from 1% to 63% across districts. Gunnala et al. (2016) attribute this variation largely to lack of knowledge about vaccines and immunization services. For this reason, we concentrate on the role of maternal education in improving immunization rates in Nigeria.

3. Maternal education and child health

Perhaps the most common mechanisms linking maternal education to child health are employment and income. Formal education contributes to critical thinking, problem-solving, communication, and other skills that are critical for business and entrepreneurship (Idris and Agbim, 2015). As a result, educated women are more likely to engage in income-generating activities, find formal sector employment outside the home, and earn higher wages. Indeed, education is a key determinant of income (Oyetso and Olomukoro, 2012). In turn, employment and income influence child health in several ways. First, working mothers and wealthy households are more likely to use health services because they have the capacity to pay for medical care (Adedokun et al., 2017). Second, women and men tend to spend money differently, and putting income under women's control raises household allocations toward health (Angel-Urdinola and Wodon, 2010; Gummerson and Schneider, 2013). Third, as a woman's contribution to household income increases, so does her decision-making power within the household (Angel-Urdinola and Wodon, 2010). The more freedom a woman has to make decisions, the more likely she is to make timely choices about using health services and immunizing sick children (Fawole and Adeoye, 2015; Smith et al., 2003).

Indeed, another way in which maternal education influences child health is through greater health knowledge and use of health services. Knowledge about the safety and importance of vaccines is one of the most important factors in getting mothers to immunize their children in Nigeria (Gidado et al., 2014; Gunnala et al., 2016; O dusanya et al., 2008), especially since fears and myths about adverse consequences promote distrust in routine vaccinations (Renne, 2006). In general, educated women tend to be more aware of health issues, understand the importance of healthcare, and know where to find healthcare services (Somefun and Ibisomi, 2016). They also have better communication skills that allow them to navigate bureaucratic health systems and interact more effectively with medical personnel (Vickram, Vanneman and Desai, 2012). As a result, evidence from Nigeria shows that more highly educated women are more likely to utilize health services for sick children (Adedokun et al., 2017) and to give birth in a health facility (Onah et al., 2006). Hospital delivery, which is often used as a proxy for access to and use of health services, is generally associated with better child health outcomes (Karra et al., 2017). But it may be particularly important for the completion of child immunizations in Nigeria, as the first dose of the polio vaccine is administered at birth (National Population Commission [NPC & ICF International, 2014]).

3.1. Community-level effects of women's education

One comparatively understudied aspect of women's education is the possibility that it may have beneficial effects on child health at multiple levels. A small, but growing body of research examines the importance

Table 1
Nigeria compared to sub-Saharan Africa and lower middle-income countries.

<table>
<thead>
<tr>
<th></th>
<th>Nigeria</th>
<th>Sub-Saharan Africa</th>
<th>Lower Middle-Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP per capita (constant US dollars)</td>
<td>2456</td>
<td>1639</td>
<td>2117</td>
</tr>
<tr>
<td>DPT immunization rate (%)</td>
<td>49</td>
<td>74</td>
<td>82</td>
</tr>
<tr>
<td>Infant mortality rate (per 1000 births)</td>
<td>67</td>
<td>53</td>
<td>38</td>
</tr>
<tr>
<td>Under 5 mortality rate (per 1000 births)</td>
<td>104</td>
<td>78</td>
<td>51</td>
</tr>
<tr>
<td>Life expectancy</td>
<td>53</td>
<td>60</td>
<td>68</td>
</tr>
</tbody>
</table>

Notes: Based on latest available data (2016) from World Bank World Development Indicators.
of contextual and community effects for child health in developing countries, which are ignored by conventional OLS regression models (e.g., Babalola, 2009; Sastry, 1996; Shin, 2007). Several multi-level studies in India, for instance, demonstrate that women's education and literacy at the individual and the community level significantly affect child mortality (Kravdal, 2004), immunization rates (Parashar, 2005), and malnutrition (Luke and Xu, 2011; Moestue and Hutty, 2008).

Such studies reveal that the principle determinant of a woman's autonomy may not be whether she is educated herself, but whether she lives in a community where a majority of women are educated. Educational opportunities may institute new social norms at the macro level that provide leverage for women to renegotiate relationships with men at the individual level (Dharmalingam and Morgan, 1996). “Mass education” is beneficial for everyone because it institutes broad transformations in family relationships (Caldwell, 1980). As broad societal transformations take place, a large number of educated women may shape other women's capacity to seek and take advantage of better access to services, skills, and information. Furthermore, educated females may begin to transform social institutions, promote the growth of public services, and mobilize resources that could help satisfy their own and other women's needs, resulting in a dispersal effect of expanded female education on health (Parashar, 2005).

For example, educated mothers may have useful knowledge about the prevention of illness, which can be imitated by other parents (Luke and Xu, 2011). Educated mothers are also more likely to engage in health-promoting behaviors, which can have spillover effects on other families in the community (Desai and Alva, 1998). In communities where women attain high levels of education on average, the fertility of even uneducated women is lower than otherwise expected (Cleland and Jejeebhoy, 1996). This example illustrates that as education promotes women's autonomy in the aggregate, this reinforces changes in gender norms and can empower individual women to take actions that will benefit their own and their children's wellbeing (Koenig et al., 2003; Luke and Xu, 2011). Thus, women's educational expansion may have a protective effect on child health not only because more women attain higher levels of education, but also because everyone, even the uneducated, benefits from the higher educational level of the community (Kravdal, 2004).

4. Methods

4.1. Data and sample

We draw on data from the DHS, a collection of nationally representative, population-based surveys conducted in developing countries. The analytic sample used here includes communities with available data on the dependent variable collected during the latest phase of the DHS in Nigeria (NPC & ICF International, 2014). The enumeration areas (EAs) specified by the National Population Commission of Nigeria provide the sampling frame for the 2013 Nigerian survey. The DHS then selects the sample using a stratified three-stage cluster design which yields 904 clusters (372 clusters in urban areas and 532 in rural areas). The sample is representative of the Nigerian population at the national, state, local government, and locality levels with the use of sampling weights provided by DHS.

The DHS is unique in that it provides geocoded information for each observation. Specifically, every child is paired with a DHS cluster ID number that uniquely identifies, geographically and numerically, the primary sampling unit (PSU) each individual belongs to. From this data, we utilize the geospatial analysis tool ArcGIS to aggregate children into communities, which we define as local government areas (LGAs). LGAs are the third tier of government in Nigeria (after the state and federal governments) and are responsible for the provision of health services, including immunizations. Additionally, residents of LGAs tend to have many things in common such as schools, markets, language, cultural practices, and norms. This suggests that the LGA is an appropriate measure of community (Babalola, 2009).

The data are aggregated into communities in several steps. First, we obtain a map of the geopolitical divisions of LGAs in Nigeria from the GADM Database of Global Administrative Areas (GADM, 2016). Second, all DHS clusters are overlayed onto the LGAs. Finally, we perform a spatial join of the two datasets (Price, 2016). The spatial join (1) assigns each child to their appropriate LGA and (2) aggregates the individual-level data from DHS clusters within each LGA. This allows us to create average measures of maternal education, maternal employment, wealth, and hospital access for each community.

The DHS provides information on children under the age of 5. As is standard practice in immunization research, we limit the analysis to children aged 12–24 months. Thus, the analysis pools data on 6052 children aged 12–24 months in 455 communities. Babalola (2009) sets the upper limit at 36 months because children in Nigeria begin and complete their immunization schedules late. For this reason, we restrict the sample to 12–36 months and 12–59 months in additional sensitivity analyses not shown, and the results remain the same. Regardless of whether the upper age limit is 59, 36, or 24 months, the effects of maternal education are notably robust and consistent.

4.2. Estimation technique

We estimate a series of hierarchical generalized linear models (HGLM) with the HLM 7.01 software developed by Raudenbush et al. (2004). These models predict the odds that a child is fully immunized based on a set of both community- and individual-level explanatory variables. This is a common technique for dealing with a nested data structure and dichotomous dependent variables (e.g., Burroway, 2016; Magadi, 2011). The advantage of this technique is that the net effects of one level can be estimated while controlling for variation in the other level. Ignoring the nesting of observations within clusters violates the assumption of independent standard errors and inflates the risk of a Type 1 error. However, hierarchical analysis provides unbiased and efficient estimates of the coefficients, as well as proper standard error estimates (Guo and Zhao, 2000; Raudenbush and Bryk, 2002).

The intraclass correlation coefficient (ICC) measures the amount of variance explained simply by living in the same community (Gelman and Hill, 2007). The ICC for this analysis is 0.456, which means that approximately 46% of the variation in immunizations stems from differences between communities. The ICC underscores the contribution of this study by suggesting that traditional regression models relying on individual-level data are misspecified. They cannot explain a large portion of the variation in immunizations. Omitting the community-level variables leaves out an important part of the story.

While we acknowledge that children are nested within households, and standard errors are clustered within households, other scholars using DHS data do not view this as problematic since the number of children under the age of 24 months per household is relatively small (Fotsu, 2006). In addition, this within-household clustering is controlled for by the modeling technique (Bryk and Raudenbush, 1992). However, as a robustness check in additional analyses not shown, we limit the sample to one child chosen randomly per household. The main results and conclusions remain the same.

The variables are group-mean centered at level 1. This implies that an individual's relative position within a community influences the outcome. This is appropriate for comparisons in which levels of wealth or education, for example, may have different value depending on context (Enders and Tofighi, 2007). We assess the potential influence of outliers using Cook's distance statistics, but do not find influential cases that alter the results. We also estimate the models with robust standard errors to correct for potential heteroskedasticity (Raudenbush et al., 2004). Finally, we examine correlation matrices and variance inflation factors (VIF) to assess possible multicollinearity among variables. The VIF for all variables is below 5, except for education (5.74). Though there are no definitive cutoffs, some scholars suggest that VIFs should
be less than 10 (Petraitis et al., 1996). In addition, we conduct a variety of sensitivity analyses (not shown) to ensure that collinearity does not influence the main conclusions.

4.3. Dependent variable

The dependent variable is a dichotomous measure indicating whether or not a child is fully immunized. Immunizations are either reported by the mother or recorded on a child’s vaccination card. In Nigeria, a child should receive nine vaccines: one dose of BCG (Bacillus Calmette-Guérin) for tuberculosis, 3 doses of DPT (triple vaccine for diphtheria, pertussis, tetanus), 4 doses of polio, and 1 dose of measles. A child who receives all 9 vaccines is coded as 1, and all others are coded as 0. In supplementary analyses (Supplementary Table 1), we examine 4 other ways of operationalizing the dependent variable. The results for education at both levels are remarkably consistent, underscoring the robustness and validity of the main findings.

4.4. Individual-level independent variables

Mother’s education is the main independent variable of interest and is measured in years. We also include three potential mediating variables: employment, wealth, and hospital use. Mother employed is a dichotomous variable, coded as 1 for currently employed and 0 for unemployed. Household wealth is measured as a composite index that represents the cumulative living standard of a household. Following previous research (Heaton et al., 2005), this index is calculated as the percentage of household items (including sanitation facilities, clean water, radio, television, electricity, refrigerator, bicycle, motorcycle, car, and telephone) present in the home. Asset-based measures of wealth are widely used to indicate socioeconomic status because very few demographic surveys gather data on income or consumption expenditures in developing countries (Bollen et al., 2001). Hospital birth is a dichotomous variable coded as 1 if the child was born in a hospital or medical facility.

In addition, the models control for a variety of other characteristics that could influence immunizations. A dichotomous variable indicates the presence of a female household head (coded as 1 for yes and 0 for no). Female headed households are more likely to experience poverty than other households (Buvnic and Gupta, 1997), which suggests that they may not have the financial capacity to have their children fully immunized. Religion is measured as a series of dichotomous variables including Christian, Catholic, and other, with Muslim as the omitted reference group. Muslim households tend to have lower rates of vaccine uptake than other religious groups (Babalola, 2009). Household size is measured as total number of persons living in the household. A child’s health needs can be compromised in large families where limited resources are shared among many (Heaton et al., 2005). Birth order is measured as a continuous variable where the eldest child has the lowest birth order. Large numbers of children reduce the time and resources necessary to care for each child, thus higher order children are less likely to be immunized (Fatiregun and Okoro, 2012). Child’s sex is coded as 1 for male and 0 for female. Male children may be more likely to be immunized when there is a strong preference for sons (Parashar, 2005). Mother’s age (in years) and child’s age (in months) are also included.

4.5. Community-level independent variables

Following previous research that similarly uses DHS data, community-level variables are derived from individual-level information (e.g., Magadi, 2011; Ononokpono et al., 2014). Maternal education at the community level is measured as the average years of education for all mothers within each local government area. Maternal employment is obtained by calculating the percentage of mothers in each local government area that are employed in paid labor at the time of the survey. We also include average household wealth at the community level in order to ensure that the effects of women’s education and employment are independent of a community’s level of prosperity. This is calculated by taking the average of the household wealth index for each local government area. We assess the availability and use of health services in the community by including the percentage of hospital births.

Two additional community-level variables are included as controls. The percentage of urban households measures the extent of urbanization in a community. Urban areas provide better access to education and health care services (Brady et al., 2007). And, we include a dichotomous variable indicating that the community is in the Northern region of Nigeria. Previous research shows that the North performs more poorly than the South on immunization coverage (Babalola, 2009). Descriptive statistics for all variables in the analysis are provided in Appendix A.

5. Results

Before turning to the regression models, it is helpful to see the distribution of childhood immunization uptake and women’s education across Nigeria. We present the results of the spatial analysis in Figs. 1 and 2. Fig. 1 displays the prevalence of fully immunized children, divided by quintiles (values are rounded for ease of interpretation). The map shows considerable variation across communities. In the first quintile, or lowest 20 percent of communities in Nigeria, 0 to 10 percent of children are fully immunized. In the fifth quintile, or highest 20 percent of communities, between 40 and 100 percent of children are immunized. On one hand, such spatial disparities across communities are obscured by country-level, cross-national analyses of child health that treat Nigeria as one case, without investigating the variation within. On the other hand, individual-level studies fail to account for the fact that vaccine uptake is concentrated in certain communities. This suggests that structural factors beyond the household may be influencing the likelihood that children are fully immunized.

Figure two presents the distribution of maternal education by community, again divided into quintiles. Values represent the average amount of education in each community. The map shows a similar pattern of variation across communities. In the lowest quintile, women have only 0–2 years of education on average. In the highest quintile, they have over 12 years. Comparing the figures shows that there are many areas that have both low levels of maternal education and low rates of immunization. The geospatial analysis uncovers glaring disparities in the distribution of immunizations and education across Nigeria, despite the overall level of economic growth. Although it is widely assumed that the benefits of economic growth will trickle down to influence wellbeing for all, this may not be the case for particularly vulnerable populations like young children.

Table 2 displays the results for hierarchical generalized linear models that estimate the odds that a child has received the full battery of immunizations. The models are sequenced in order to examine possible mediating effects. Model 1 displays the association between immunization status and maternal education, along with other relevant control variables. Model 2 examines maternal employment, Model 3 examines wealth, and Model 4 examines hospital use. Model 5 combines all of these variables in a final model.

Beginning with mother’s education, Model 1 shows that education at both the individual level and the community level has a significant association (p < .001) with vaccine uptake. For each one-year increase in a mother’s education, the odds of a child receiving all of the prescribed vaccinations increase by a factor of 1.097. At the community level, each one-year increase in average education, the odds increase by a factor of 1.336. Thus, the education level of a child’s own mother influences the likelihood of being immunized, but above and beyond that, living in a community in which many women are educated also influences that likelihood. Educational expansion benefits child health not only because individual women reach higher levels of formal
schooling, but also because everyone benefits from the higher educational level of the community.

Model 2 shows that with the addition of maternal employment, the effects of maternal education remain relatively unchanged at both levels. In Models 3 and 4, maternal education again remains robustly significant at both levels when household wealth and hospital use are introduced into the models. With the addition of each mediating variable, the coefficient for education attenuates only slightly in size. The final model of Table 2 combines education, employment, wealth, and hospital use. The findings remain relatively unchanged compared to previous models. In Model 5, for every additional year of maternal education, the odds that a child is fully immunized increase by a factor of 1.057 at the individual level. At the community level, for each one-year increase in average education, the odds increase by a factor of 1.222. Thus, the beneficial effect of mother’s education is robust and only partially mediated by employment, wealth, and hospital use.

Recognizing that years of education represents one way among many to measure this variable, we present additional possibilities in the supplementary analyses. In Supplementary Table 2, we present final models using categorical measures of education at both levels (primary, secondary, and tertiary, with no education as the reference group). This table further illustrates the consistency of the education effects. In Supplementary Figure 1, we graph the relationship between vaccination rates and the proportion of women in a community who are educated at the secondary level or higher. This depicts levels of vaccination at all levels of secondary education, from low to high. The graph reveals...
organization has a signiﬁcant positive association with vaccine uptake in Models 1 and 2. However, this effect attenuates to insigniﬁcance when wealth is added in Model 3. This suggests that one way in which urbanization contributes to child health is by providing households with better economic opportunities. This is in line with previous research that shows urban areas provide more diverse job opportunities, greater income, and a higher quality of life (Bloom et al., 2008). Wealth also has a significant positive association with vaccine uptake at the community level, even in the final model controlling for the full set of community characteristics. Thus, wealthier communities also seem to be healthier communities.

At the individual level, the final model also shows that children are more likely to be fully immunized when they are from wealthy households. In addition, being born in a hospital has a robust association with vaccine uptake. This makes sense given that babies in Nigeria receive their ﬁrst vaccinations at birth. Children of older mothers are more likely to receive the full prescription of vaccinations, and children from non-Muslim households are more likely to be immunized. Finally, higher birth order children are less likely to be fully immunized, which indicates that the time and resources necessary to care for children are depleted with additional births.

### Table 2

<table>
<thead>
<tr>
<th>Community Level</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average maternal education (years)</td>
<td>1.336***</td>
<td>1.334***</td>
<td>1.266***</td>
<td>1.280***</td>
<td>1.222***</td>
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<tr>
<td>Maternal employment (%)</td>
<td>.290</td>
<td>.289</td>
<td>.286</td>
<td>.266</td>
<td>.201</td>
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<td>Urban households (%)</td>
<td>1.441*</td>
<td>1.443*</td>
<td>1.161</td>
<td>1.307</td>
<td>1.077</td>
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<tr>
<td>Northern region (%)</td>
<td>.365</td>
<td>.367</td>
<td>.149</td>
<td>.268</td>
<td>.074</td>
</tr>
<tr>
<td>Mother’s education (years)</td>
<td>.910**</td>
<td>.907**</td>
<td>.914**</td>
<td>.923*</td>
<td>.923*</td>
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<tr>
<td>Mother employed (%)</td>
<td>.893</td>
<td>.903</td>
<td>.568</td>
<td>.077</td>
<td>.055</td>
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<tr>
<td>Household wealth index</td>
<td>1.188</td>
<td>.172</td>
<td>1.020**</td>
<td>.020</td>
<td>.019</td>
</tr>
<tr>
<td>Household birth</td>
<td></td>
<td></td>
<td>.978</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital birth (%)</td>
<td></td>
<td></td>
<td>.918</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female household head (%)</td>
<td>1.122</td>
<td>1.125</td>
<td>1.304</td>
<td>1.108</td>
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<td>Religion</td>
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<td>.266</td>
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<tr>
<td>Christian</td>
<td>1.396</td>
<td>1.381</td>
<td>1.615***</td>
<td>1.397**</td>
<td>1.590***</td>
</tr>
<tr>
<td>Catholic</td>
<td>.334</td>
<td>.323</td>
<td>.479</td>
<td>.334</td>
<td>.464</td>
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<tr>
<td>Other</td>
<td>1.231</td>
<td>1.191</td>
<td>1.460</td>
<td>1.186</td>
<td>1.349</td>
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<tr>
<td>Household size (%)</td>
<td>.999</td>
<td>.999</td>
<td>.988</td>
<td>.999</td>
<td>.999</td>
</tr>
<tr>
<td>Birth order</td>
<td>.001</td>
<td>.001</td>
<td>.012</td>
<td>.001</td>
<td>.010</td>
</tr>
<tr>
<td>Male</td>
<td>.094</td>
<td>.097</td>
<td>.090</td>
<td>.080</td>
<td>.080</td>
</tr>
<tr>
<td>Child’s age (months)</td>
<td>.990</td>
<td>.989</td>
<td>.991</td>
<td>.990</td>
<td>.990</td>
</tr>
<tr>
<td>Mother’s age (years)</td>
<td>1.031**</td>
<td>1.030**</td>
<td>1.028**</td>
<td>1.027*</td>
<td>1.027*</td>
</tr>
</tbody>
</table>

Notes: * indicates p < .05, ** indicates p < .01, and *** indicates p < .001 for a two-tailed test. Each cell contains the odds ratio and the unstandardized logistic coefﬁcient in italics.

### 6. Conclusion

The results suggest that studies conﬁned to an individual-level perspective fail to uncover the entire impact of women’s education on child health. The effects of education are not limited to the mother-child pair (Mosthue and Hutty, 2008). Rather, the average level of education in a community brings beneﬁts to children above and beyond the beneﬁts wrought by their own mother’s educational attainment. The robustness of this ﬁnding underscores its importance. The effects of education at the community level remain stable across model speciﬁcations in Table 2. In constant sensitivity analyses, some of which are not shown and some of which are displayed in the supplementary materials, the results remain consistent. Regardless of various sample restrictions, measures of education, and measures of immunizations, the story remains the same. Education at the community level has a spillover effect, whereby everyone beneﬁts from having more educated women in the community, even the children of uneducated women.

This analysis contributes to the vast literature on maternal education and child health in several key ways. We concentrate on a country that presents a bit of a development puzzle. Nigeria is an interesting case since it does not follow the conventional wisdom that economic growth fosters better wellbeing. We use geospatial analysis in order to help solve this puzzle. The maps displayed in Figs. 1 and 2 reveal sizeable disparities in vaccine coverage and education across Nigeria, despite the overall level of economic growth. While it is often assumed that a rising tide lifts all boats, the maps show that this is not the case. Not everyone gains from the presumed beneﬁts of economic growth, as evidenced by the fact that child health is very unequally distributed across Nigeria. If economic growth does not necessarily contribute to better child health, then what does?

Our ﬁndings suggest that education is key. But, the analysis goes beyond the traditionally used indicators of education that are measured at either the individual or the country level. This study answers the call of previous scholars (e.g., Desai and Alva, 1998; Vickram et al., 2012) who emphasize the need for multi-level estimation techniques to overcome the limitations of traditional OLS regression models in immunization research. As such, we contribute to studies of health more broadly by suggesting that the meso-level (i.e., the community) is an important source of variation that deserves to be explored more fully. In the Nigerian case, 46% of the variation in immunization rates is due to differences across communities. This means that any explanation of immunization disparities in Nigeria that omits the community context is incomplete. Although the generalizability of this case study is limited, it establishes community-level effects as a fruitful area for future research on health in developing countries.

Of course, this study raises additional questions about exactly how and why maternal education beneﬁts child health. We examine several potential mechanisms through which education operates to improve vaccination rates: employment, wealth, and hospital use. But the odds ratios for education at both levels do not vary much with the inclusion of these mediators. That is, the education effect is not explained away by these factors. Using DHS data for 22 developing countries, Desai and Alva (1998) similarly ﬁnd that the relationship between maternal education and immunization rates remains, even after controlling for a variety of relevant factors. Other researchers also note that the relationship between education and immunizations is difﬁcult to disentangle (Parashar, 2005). Thus, there is still much we do not know about the link between education and vaccine uptake. Unfortunately, research utilizing the DHS is limited by some data constraints in this regard. The dataset does not include a direct measure of income or household consumption, nor does it provide a direct measure of health knowledge.

In addition to the mediating variables considered here, many

higher birth order children are less likely to be fully immunized, which indicates that the time and resources necessary to care for children are depleted with additional births.
scholars emphasize empowerment as the chief explanatory factor connecting maternal education to improved wellbeing (e.g., Oyitso and Olomukoro, 2012). But “empowerment” is a vague and elusively defined term that is difficult to measure (Burroway, 2015). Furthermore, the standard R² term in traditional regression analysis does not apply to multi-level analysis and software programs do not provide an equivalent (Recchia, 2010). This means that we cannot report the proportion of variance explained by education or other predictors. We acknowledge that there could be some unexplained variation in vaccination rates owing to factors that we were not able to include, such as women’s political participation, distance to a health facility, or health knowledge. Given the proliferation of scholarly interest in women’s education, this remains a promising area for future research and data collection efforts. We also acknowledge that community-level education could potentially moderate the relationship between the individual-level predictors and vaccination rates. That is, community education could exacerbate or mitigate immunization disparities based on religion, hospital births, etc. Although such cross-level interaction effects are beyond the scope of this paper, this is another promising area for future research.

Uthman (2009) notes the need to scale up targeting strategies in Nigeria that are meant to reduce inequality and improve living conditions for the most marginalized populations. The results of this research support and aid these recommendations by revealing the very communities that are most disadvantaged in regard to child immunizations. After all, targeting is most effective when priorities can be assigned based on empirical data (Agee, 2010), and this study provides such data. However, public policies that focus exclusively on immunization targets must shift their focus to include education as well (Parashar, 2010). This means that we cannot report the proportion of variance explained by education, but it also requires the ability to access them (Fawole and Adeoye, 2015). Unfortunately, access to routine immunizations continues to present a formidable challenge to mothers in Nigeria. Sufficient access stems not only from reasonable traveling distances to health facilities, but also from well-stocked supplies of vaccines at those facilities and the availability of trained staff to administer vaccines. Thus, successful immunization campaigns require that staff and services be equitably distributed around the country (Ebareime et al., 2015). Policies to support maternal education must be combined with efforts to increase outreach services, establish new health facilities, or relocate existing facilities to more adequately cover the population (Fatiregun and Okoro, 2012).

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Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.socscimed.2018.07.036.

Appendix A. Descriptive statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Mean (Std. Dev.)</th>
<th>Range</th>
<th>Pearson's r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community Level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average maternal education</td>
<td>Average education of all mothers in the community, measured in years</td>
<td>6.07 (4.08)</td>
<td>0 - 15.47</td>
<td>.77</td>
</tr>
<tr>
<td>Maternal employment</td>
<td>Percentage of mothers in the community that are employed</td>
<td>0.75 (0.20)</td>
<td>0.05 - 1</td>
<td>.34</td>
</tr>
<tr>
<td>Average household wealth</td>
<td>Average of the wealth index for all households in the community</td>
<td>39.60 (15.66)</td>
<td>3.90 - 70.80</td>
<td>.58</td>
</tr>
<tr>
<td>Hospital births</td>
<td>Percentage of births that occurred in a hospital</td>
<td>0.48 (0.34)</td>
<td>0 - 1</td>
<td>.72</td>
</tr>
<tr>
<td>Urban households</td>
<td>Percentage of households located in an urban area</td>
<td>0.38 (0.44)</td>
<td>0 - 1</td>
<td>.49</td>
</tr>
<tr>
<td>Northern region</td>
<td>Dichotomous variable indicating that the household resides in the north (north = 1)</td>
<td>0.55 (0.50)</td>
<td>0 - 1</td>
<td>-.53</td>
</tr>
<tr>
<td>Individual Level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fully immunized</td>
<td>Dichotomous variable indicating that a child has received all 9 vaccines (fully immunized = 1)</td>
<td>0.24 (0.42)</td>
<td>0 - 1</td>
<td>1.00</td>
</tr>
<tr>
<td>Mother's education</td>
<td>Measured in years</td>
<td>5.13 (5.38)</td>
<td>0 - 19</td>
<td>.42</td>
</tr>
<tr>
<td>Mother employed</td>
<td>Dichotomous variable indicating mother’s employment status (employed = 1)</td>
<td>0.70 (0.46)</td>
<td>0 - 1</td>
<td>.08</td>
</tr>
<tr>
<td>Household wealth index</td>
<td>Index indicating the percentage of common household items present in the home</td>
<td>37.05 (21.78)</td>
<td>0 - 100</td>
<td>.31</td>
</tr>
<tr>
<td>Hospital birth</td>
<td>Dichotomous variable indicating that a child was born in the hospital (hospital birth = 1)</td>
<td>0.39 (0.49)</td>
<td>0 - 1</td>
<td>.35</td>
</tr>
<tr>
<td>Female household head</td>
<td>Dichotomous variable indicating the presence of a female household head (female = 1)</td>
<td>0.10 (0.31)</td>
<td>0 - 1</td>
<td>.09</td>
</tr>
<tr>
<td>Religion</td>
<td>Series of dichotomous variables indicating the household’s religion, with Muslim as the omitted reference group</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Notes: The final column displays the bivariate correlation between each independent variable and the outcome variable (fully immunized).

References


Treat, J., Tai, T., 2012. Apron strings of working mothers: maternal employment and...