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A Quantitative Analysis of Determinants of Child and Maternal Malnutrition in Nigeria

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Nigeria Strategy Support Program (NSSP)

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THE NIGERIA STRATEGY SUPPORT PROGRAM (NSSP)

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- Strengthened capacity for government agencies, research institutions, and other stakeholders to carry out and use applied research that directly informs agricultural and rural polices and strategies; and
- Improved communication linkages and consultations between policymakers, policy analysts, and policy beneficiaries on agricultural and rural development policy issues.

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Abstract

Malnutrition rates among children 0-36 months and women of reproductive age in Nigeria are high and vary significantly across rural-urban locations, geopolitical regions, and agroecological zones, constituting a significant public health challenge. Using National Demographic Health Survey (NDHS) 2003 data, we sought to understand better what the determinants of child and maternal nutrition are and whether they differ significantly in terms of their nature, levels, and effects across these domains. We also sought to understand what implications any significant differences would have for policy responses. A range of socioeconomic, demographic, and public health related factors work together to influence maternal and child nutrition outcomes among rural and urban dwellers across the geopolitical regions and agroecological zones. Our analyses show some major variables that influence maternal and child nutrition including household economic status, having a household head predominantly engaged with agriculture, maternal work to earn income, and maternal education or knowledge. Other determinants include mother's age, decision-making on her income and her health, percent of children under five years in a household, child based characteristics such as age and sex, dietary diversity and meal frequency, and public health services such as having antenatal care and vaccinations. The results indicate that while the effect of some determinants cuts across many of the rural and urban regions and zones, the effects of other determinants are more localized in rural or urban settings of particular regions and zones. While maternal education and knowledge are critical for improved maternal and child nutrition, efforts to improve household economic status, increase the rural farmers' benefits from agriculture, and empower mothers to earn income and take decisions, complemented with nutritional and public health services, are more likely to improve both child and maternal nutrition in the rural areas than in urban, especially in regions with the highest burden of malnutrition. Current levels of determinants appear linked more to policy implementation challenges than to the lack of or deficient components of policies to effectively address these determinants. To substantially improve nutrition conditions of mothers and children in rural Nigeria, strengthening or reviewing current policy and implementation processes in key areas is critical.

Key words: child and maternal malnutrition, regions, agroecological zones, policy

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List of Abbreviations and Acronyms

ACC/SCN	Administrative Coordinating Committee/Standing Committee on Nutrition
AU	African Union
BCG	Bacillus Calmette-Guerin
BMI	Body Mass Index
CDC	Center for Disease Control
CED	Chronic Energy Deficiency
DHS	Demographic and Health Survey
DHW	Durbin-Wu-Hausman Test
FAO	Food and Agriculture Organization
FEWS NET	Famine Early Warning Systems Network
FMANR & RD	Federal Ministry of Agriculture and Natural Resources and Rural Development
FMOH	Federal Ministry of Health
HAZ	Height-for-age Z-score
NAP	National Agricultural Policy
NBS	National Bureau of Statistics
NCHS	National Centre for Health Statistics
NDHS	Nigeria Demographic and Health Survey
NEPAD	New Partnership for African Development
NFCNS	Nigeria Food Consumption and Nutrition Survey
NPC	National Population Commission
OLS	Ordinary Least Square
PCA	Principal Component Analysis
PHC	Primary Health Care
2SLS	Two Stage Least Squares
UNICEF	United Nations Children Fund
WHO	World Health Organization

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Introduction

Many studies have confirmed significant variations in the level of malnutrition across rural-urban settings, geopolitical zones, and broad agroecological bands in Nigeria (NPC/ORC Macro 2004; Maziya-Dixon et al. 2004; NPC/ICF Macro 2009). Generally, many of these studies agree with the findings that the hungry and malnourished tend to be located primarily in rural agricultural areas and hunger and malnutrition are more acute among the landless, pastoralists, smallholders, and hired agricultural workers (Southgate et al. 2007; AU/NEPAD 2007). Over 60 percent of Nigerians live in rural areas and principally draw their livelihoods from agriculture (NBS 2005).

However many of these studies are essentially descriptive in nature and lack detailed analysis of socioeconomic and proximate determinants of child and maternal malnutrition in the various geopolitical regions and agroecological bands that would more effectively guide policy interventions in these areas. This study, therefore, seeks to provide some understanding of the key determinants of child and maternal malnutrition among vulnerable households that pursue agricultural livelihoods predominantly located in rural Nigeria in comparison with households in corresponding urban settings. The study is premised on the understanding that the sources of vulnerability such households face include physical factors related to health and nutritional status and economic factors related to the sustainability and efficacy of the rural livelihood strategies pursued by household members, and that the characteristics of these households, as well as the shocks they face and the resources they can draw upon differ across Nigeria.

Using data from the 2003 Nigeria Demographic and Health Survey (NDHS), this analysis seeks to deepen the understanding of determinants of nutritional status of children 0 to 3 years old in rural and urban households. The specific objectives are to

- identify household and community characteristics and regional-specific risks that affect malnutrition in children 0-3 years and adult women of gestational age,
- develop a set of typologies of vulnerability to malnutrition based on this assessment,
- assess how current nutritional strategies and interventions do or do not address these determinants, and to
- recommend improvements in policies and programs.

Child and Maternal Nutrition in Nigeria

The 2003 National Demographic Health Survey (NDHS) shows that nationally 38 percent of children under five years are stunted, 29 percent are underweight, and 9.2 percent are wasted (NPC/ORC Macro 2004). Stunting refers to shortness that is a deficit or linear growth that has failed to reach genetic potential reflecting long-term and cumulative effects of inadequate dietary intake and poor health conditions (ACC/SCN 2000). When weight is low for age, underweight is referred to, while wasting is a recent and severe process that has produced a substantial weight loss, usually as a

consequence of acute food shortage and or severe disease. All these indices were reported based on the NCHS/CDC/WHO International Growth Reference. The Nigerian Food Consumption and Nutrition survey (NFCN 2001-2003) reported similar trends with 42 percent stunting, 25 percent underweight, and 9 percent wasting (Maziya-Dixon et al. 2004). Significant variations were reported across rural and urban regions, geopolitical, and agroecological zones. The 2003 NDHS showed that rural children (43 percent stunted) are disadvantaged compared to urban children (29 percent stunted) and children living in the North West geopolitical zone stand out as being particularly disadvantaged (percent stunted in North West is 55, compared to 43 in the North East, 31 in North Central, 20 in the South East, 21 in the South South and 25 in the South West). Among the three broad agroecological zones used in the NFCNS 2001-2003, the stunting rate was 58 percent in the dry savannah, about 46 percent in the moist savannah and lowest (27 percent) in the humid forest zone. Similar patterns were reported for underweight and wasting.

The NFCNS 2001-2003 survey showed that 11.6 percent of women of child bearing age were chronically energy deficient (CED) or underweight or thin (Body Mass Index < 18.5). The proportion of underweight women was as high as 16.4 percent in the dry savannah, 10 percent in the moist savannah and 9 percent in the humid forest zone. The NDHS 2003 reported 15 percent prevalence of chronic energy deficiency among women, ranging from 7 percent in the North Central to 23 percent in the North East and about 16 percent CED among rural women compared to 13 percent among urban women.

Data

The data for this paper are drawn from the 2003 Nigeria Demographic Health Survey. The Nigeria 2003 DHS data provides a nationally representative sample of over 7000 households with reference to over 7000 women of age 15-49 years and over 4000 children under five years with complete and plausible anthropometric data. The original dataset for the child had a sample size of 6029 children with anthropometric data. When height-for-age values less than -6 and greater than +6 standard deviations were excluded from analysis as recommended by CDC/WHO to eliminate all possible outliers, the sample size was reduced to 4293. In line with the focus of the study on children 0-36 months, older children were removed from the sample resulting in a sample size of 2822. In analyzing for determinants of nutritional status of women of reproductive age, a separate data set was used with an original sample size of 7620. On excluding possible outliers as well as all pregnant women from the analysis, the sample size was reduced to 6606. The DHS data set was preferred for this study for considerations of national representativeness, comparability across countries, availability of data sets for several points for in-country comparisons over time or trend analysis spanning many years (in Nigeria 1990, 1993, 2003, and 2008), meeting essential data needs for policy analysis, and ease of accessibility.

Model

This paper focuses on the impact of socioeconomic and demographic factors on child and maternal nutritional status. In our selection of potential determinants of malnutrition, one is guided by the available data in the DHS datasets, the conceptual framework for the causes of child malnutrition (UNICEF 1990), as well as considerations for any

variables known to be of considerable interest for policymaking and interventions. Although the UNICEF conceptual framework is comprehensive, incorporating both biological and socioeconomic causes of malnutrition at several levels, the range of socioeconomic, demographic, and biological variables available within the DHS dataset fits better with the underlying causal level of the framework. Thus, this paper focused at modeling the underlying determinants of maternal and child nutrition.

At the underlying level, the determinants include household food security, care of the child and mother, health services, and healthy environment. Food security is achieved when a person has access to enough food to lead a healthy life. The resources necessary for gaining access to food are food production, income for food purchases, or in-kind transfers of food. The DHS dataset did not include direct food security (per capita energy intake), income, or expenditure variables, or price variables. However, the household economic status measured by the household wealth index was used as a proxy for income and household access to food. Other household socioeconomic and demographic characteristics that potentially could influence household food security such as the sex, age, as well as occupational and educational status of household head and mother are considered.

It is noted that no matter how much food is available, children must have nurturing from other humans to grow (Smith and Haddad 2000). This aspect of child nutrition is captured in the concept of care for children and their mothers, who give birth to children and who are commonly their main caretakers after they are born. Thus care, being the second underlying determinant, is captured by variables such as when mothers initiated breast milk, whether a child was given complementary feeding (considering age appropriate feeding frequency and giving of minimum acceptable diet), whether a child was delivered in health facility, and whether the mother attended antenatal care during pregnancy. The adequacy of such care is determined by the caregiver's control of economic resources, autonomy in decisionmaking, and physical and mental status. This explains the inclusion of variables such as mother's occupational status which reflects whether she works to earn income and whether she decides alone on the use of her earned income, her age, her physical nutritional status (Body Mass Index), and what say she has on her own healthcare. All of these resources for care are influenced by the caregiver's knowledge and beliefs. Maternal education and literacy are used to represent this aspect of care. Child related variables such as the age, sex, and birth order all of which are known to influence the level of care children get, are also included.

The third underlying determinant of child nutritional status, which includes health environment, and services, is usually measured by availability of safe water, sanitation, access to healthcare, environmental safety, and shelter. Besides access to water and toilet facilities, availability of healthcare was measured by whether mother considers distance to health services as an important constraint as well as whether the child obtained Vitamin A supplementation service and basic immunizations.

Other factors, though not definitively addressed in this paper, that influence malnutrition from the basic level include poverty and a range of political, economic, and cultural factors that influence potential resources at community or country levels which are in turn influenced by natural environment, access to technology, and the quality of human resources. The conceptual framework is usually placed in the context of a multi-member household economic model and has been substantially elaborated on in several studies using Ordinary Least Square (OLS) regressions in which the separate effects of the

range of socioeconomic, demographic, service, and biological variables are determined. Variables that may violate the assumptions of OLS are tested for endogeneity before estimating the final model as unbiased and consistent estimates can be obtained using OLS if the error term does not contain components that are correlated with an explanatory variable (Garrett and Ruel 1999; Smith and Haddad 2000; Smith, Ruel, and Ndiaye 2004).

The paper is also focused on capturing how regional and agroecological differences influence maternal and child nutritional status. Nigeria has six geopolitical regions that reflect major ethnic, cultural, geographic, and political blocks. The DHS data are collected around these geopolitical divisions. However, there have also been concerns about understanding how agroecological differences influence maternal and child malnutrition. This is especially important as Nigeria is still a predominantly agricultural country with over 60 percent of the inhabitants and a much higher proportion of rural dwellers depending on agriculture. Using the agroecological zones links nutritional status to types of farming systems, crops grown and consumed (Maziya-Dixon et al. 2004). The agroecological zone approach better captures the range of agroclimatic, natural resource, and livelihood contexts that work together to impact on the wellbeing of mothers and their children (Dutta, Pant, Kumar, and Singh 2004).

Agroecological groups broadly organize people into coherent areas where relatively broad and similar options for obtaining food and income exist and where similar market systems operate or where people share similar livelihood patterns. Households in a particular agroecological zone are more likely, at least on a broader scale, to face similar hazards such as drought, floods, market challenges, and diseases or epidemics. Although agroecological zones align as much as possible with the administrative or geopolitical regions, they usually transcend geopolitical boundaries and are much more encompassing since they are principally delineated by considerations related to nature (rainfall, vegetation, and topography) rather than political considerations. Thus, understanding the determinants from an agroecological point of view enriches our understanding of determinants of maternal and child nutrition in a largely agrarian society. For this study, four agroecological zones are considered: Sudano Sahelian, Guinea and derived savannahs and the humid forest zone (Figure 1).

Dependent Variables

For the child models, the Z-score of the height-for-age of the child was used. Height-for-age more than two standard deviations below the NCHS/CDC/WHO reference height reflects growth failure and serves as the best general proxy for constraints to human welfare of the poorest, including dietary inadequacy, infectious diseases, and other environmental health risks (Beaton 1990; Baghiigwa and Younger 2005). It, thus, captures the multiple dimensions of individual health and development and their socioeconomic and environmental determinants and correlates well with poverty indices. It has been suggested that since stunting has a more socioeconomic dimension it should be viewed, interpreted, and applied in a broader context and not merely in a narrow biomedical sense (Zere and McIntyre 2003). There are indications that stunting (low height-for-age) in children below the age of five is a stronger indicator of long-term hunger and of one of its determinants, poverty, than other anthropometric indicators or estimates of per capita income (SCN 2008). This is because stunting indicates the chronic restriction of a child's potential growth, reflecting the cumulative effects of inadequate food intake and poor health conditions that result from endemic poverty.

For the women's model, the Body Mass Index (BMI) is used to reflect the nutritional status of mothers. Some evidence in developing countries indicates that malnourished women, with a BMI below 18.5, show a progressive increase in mortality rates as well as increased risk of illness (Girma and Genebo 2002). The BMI, which incorporates both height and weight and provides a better measure of thinness and obesity than weight alone, is defined as weight in kilograms divided by the square of the height in meters (kg/m^2). For BMI, a cut off of 18.5 has been recommended for indicating chronic energy deficiency among non pregnant women (ACC/SCN 2000).

Independent Variables

Household Economic Status (Wealth Index)

Wealth Index (Quintile) is an indicator of economic status of households. It was constructed using household asset data and principal components analysis. Asset information was collected in the 2003 DHS Household questionnaire and covers information on household ownership of a number of consumer items ranging from a television to a bicycle or car, as well as dwelling characteristics such as source of drinking water, type of sanitation facilities, and type of flooring material used (NPC/ORC Macro 2004). To assign the indicator weights, principal components analysis (PCA) was used as recommended by Filmer and Pritchett (2001). The SPSS factor analysis procedure used first standardizes the indicator variables (calculating Z-scores); then the factor coefficient scores (factor loadings) are calculated; and finally, for each household, the indicator values are multiplied by the loadings and summed to produce the household's index value (Rustein and Johnson 2004). It has been tested in a number of countries in relation to inequities in household income, use of health services, and health outcomes (Rutstein 2004; Rutstein et al. 2000). It is an indicator of the level of wealth that is consistent with expenditure and income measures (Rutstein 1999). Thus, the economic status of a household is an indicator of access to adequate food supplies, use of health services, availability of improved water sources, and sanitation facilities which are prime determinants of child and maternal nutritional status (UNICEF 1990; Girma and Genebo 2002). This also explains why variables that were used in developing the index such as source of drinking water and access to toilet facilities are not included in the model, though used in the descriptive analyses. The five levels are: 1) lowest (poorer), 2) second (poor), 3) middle, 4) fourth (richer), 5) highest (richest). Using this asset-based indicator rather than income, the endogeneity problems normally associated with income are expected to be far less serious than usual. Thus, it is assumed that the economic status variable used is contemporaneously exogenous to household decisionmaking (Smith et al. 2003; Smith, Ruel, and Ndiaye 2004).

Occupation of Household Head and Women

These occupation based variables were meant to measure the independent effect of a woman who works to earn income on her health and that of her children, and whether the household head works primarily in agriculture or not. Almost all of the household heads have occupations and classifying them as primarily involved with agriculture or not is considered useful in understanding the impact of their occupation on maternal and child nutrition independent of the household economic status. Table 2 shows that poverty rates among household heads primarily involved with agriculture are among the highest rates compared to other professional categories since 1980. Some National Bureau of Statistics data also show that poverty in Nigeria is a rural phenomenon where

agricultural activities are most predominant and that about 85 percent of rural households participate in agriculture compared to 14 percent in urban areas and that the poor generally participate more in agriculture than the non poor (NBS 2005). Rural households in the north are more likely to participate in agriculture than in the south such that 47 percent of households participate in agriculture in Benue State (North Central) compared with less than 1 percent in Lagos State (South West).

Economic theory suggests that families in which mothers work, especially outside the home, must tradeoff the advantages of greater income against the disadvantages of less time for home food production and supervision of children's activities, and this tradeoff may result in positive, negative, or no impacts (Crepinsek and Burstein 2004). While several studies are inconclusive on the effect of maternal employment on child nutritional status (Leslie 1986; Albee 1994), others have indicated negative impact of maternal labor supply on child nutrition in Africa by reducing time available for household activities related to child development (Glick and Sahn 2001; Genebo 2002). However, Penders, Staazt, and Tefft (1999) while recognizing the possible negative impact of maternal agricultural labor participation on child nutrition in Mali indicated the possibility of using raised incomes to offset the negative impacts.

The importance of women's involvement in productive activities is predicated by the notion that since nutritional problems have their origin in social and economic systems, one of the objectives of a sound nutrition program must be to bring about changes in these systems, particularly at the household level (Rogers and Youssef 1988). And since women have a central role in the health and nutrition of children, efforts to improve nutrition must support women's capacity to generate and control income while adequate child care can be ensured through existing support systems, through flexibility in work schedule, through adequate alternate care giving, or through organized child-care services. Also when women work, it improves their social status and decisionmaking in the household which are associated with improved maternal and child health outcomes (Parvin, Ahsan, and Chowdhury 2004).

Age and Sex of Household Head, Household Size and Percent of Children Under Five

Age and sex of household head also provide indications of what resource is available for improved nutrition in the household. Very young, less educated, and female-headed households are more likely to have malnourished children than others, though the effect of female headship on nutrition is mixed (Charmarbagwala 2005).

Generally, it is known that large family sizes impact negatively on nutritional status and household welfare. However, some studies have also linked large family sizes with better nutrition. Thus, the context in question determines the effect of this variable and exploring this in the various regions and domains might be useful (Mukherjee and Benson 2003; Garrett and Ruel 1999; Charmarwabagwala et al. 2005). The percent of children under five, relative to total household size, reflects the burden of care in terms of nutrition, financial, and parental time, and thus affects nutrition outcomes, while also reflecting the place of appropriate health enhancing population policies and measures in ensuring maternal and child health and nutrition.

Age of Mother, Highest Educational Level, Marital Status, and Decisionmaking on Mother's Earning

DHS 2003 found children born to younger mothers are disadvantaged nutritionally. Where teenage pregnancy and early marriage is rampant, children born to these mothers are likely to be malnourished. Despite emerging concerns and questions about the causal impact of maternal education on other human-capital aspects of child development, it is common knowledge that women who receive even minimal education are generally more aware than those who have no education of how to utilize available resources for the improvement of their own nutritional status and that of their families (Behrman and Rosenzweig 2002; Plug 2004; Benson 2004; Grossman 2006). Marital status of women is associated with their social and economic status that affects their nutritional status. This condition may also affect the level of resources available for the care of the child. If employed women do not have control over their income and decisionmaking authority within the household, they are deprived of the ability to take actions that will benefit their own well-being and also their children. Studies have shown that, at similar levels of income, households in which women have a greater control over their income are more likely to be food secure (Kennedy and Haddad 1991).

Mother Attending Antenatal Care, Place of Child Delivery, Birth Interval, and Giving Child Vaccination (BCG)

Attending antenatal care during pregnancy is an important component of household and community care for the mother and maternal health seeking behavior. The reproductive health services that a mother receives during her pregnancy and at the time of delivery are important for the well-being of the mother and child and represent an essential part of care for women, which is critical for nutrition improvement (ORC/Macro/NPC 2004)

Early Initiation of Breastfeeding and Feeding Solid, Semi-solid, and Soft Foods to Infants and Young Children

Based on the WHO 2008 definitions for indicators to assess infant and young child feeding practices, we created a few variables to measure infant feeding practices in this study. We defined the core indicator, early initiation of breastfeeding as children 0-24 months that were put to the breast within one hour of birth. With respect to the introduction and quality of complementary or soft, semi-solid, or solid foods, we generated variables such as minimum dietary diversity and meal frequency from the DHS data based on how many times children 6-11, 12-23 and 24-36 months received solid, semi solid or soft foods the day previous to the survey and on how many times the child was fed from various food groups same day. We constructed minimum acceptable diet, a summary infant and young child feeding indicator, from two variables: breastfed children in the various age groups who had at least the minimum dietary diversity and the minimum meal frequency for their age groups during the previous day.

The minimum dietary diversity is defined as the proportion of children in the various age groups (6-11, 12-23, and 24-36 months) who received foods from 4 or more food groups during the previous day (Table 1). Foods were classified into seven food groups: grains; roots and tubers; legumes and nuts; fruits and vegetables; dairy products (milk, yoghurt, and cheese); meat/poultry/egg/fish; and fats and oil. The meat-poultry-egg-fish food group was combined into a single group, as the DHS data set used. This combination can help in using a single variable to evaluate the intake of animal foods. While the DHS

data have different groups of fruits and vegetables to emphasize vitamin A rich and non rich fruits and vegetables, all these groups of fruits and vegetables were combined together to form one fruits and vegetables food group for the purpose of this analysis.

The seven food groups as used in this paper differ slightly from the six food groups used by Ruel and Menon (2002) for a study of Latin American countries, but align almost completely with the eight food groups used by Arimond and Ruel (2002) for a study of an African country except that they allowed for separate groups distinguishing Vitamin A rich fruits and vegetables from others. The food groups used also vary slightly with the food groups highlighted by WHO (2008). We used a cut-off of at least 4 of the 7 food groups because this cut-off level is associated with better quality of diets for breastfed and nonbreastfed children (FANTA 2007; WHO 2008). Consumption of foods from at least 4 food groups on the previous day would mean that in most populations the child had a high likelihood of consuming at least one animal source food and at least one fruit or vegetable that day, in addition to a staple food (grain, root or tuber).

We defined the minimum meal frequency indicator as the proportion of breastfed children 6-11, 12-23 and 24-36 months of age who received solid, semi-solid, or soft foods the minimum number of times or more, as appropriate for their ages, during the previous day. For the 6-11 months age group, we used a minimum daily meal frequency of two times aside from breast milk, and for ages 12-23 months and 24-36 months, we used a minimum daily food frequency of three feedings per day. These minimum feeding frequencies reflect the feeding frequencies that were assigned the lowest positive score for the various age groups in the child feeding indices constructed by several authors, taking into consideration current feeding recommendations (Ruel and Menon 2002; Arimond and Ruel 2002; Dewey 2003; WHO 2008). The minimum acceptable diet sums those breastfed children who received both the minimum feeding frequency and dietary diversity on the day prior to the survey.

All measurements using the dietary intake indices described recognize the feeding recommendation of continued breastfeeding for children after the first six months of life through the second year of life (Black et al. 2008). Preliminary findings of our study showed that about 96 percent of children 6-11 months and 70 percent of children 12-23 months were being breastfed at the time of the study. Only about 30 percent of children 24-36 months were still breastfeeding. As beneficial as continued breastfeeding may be at this stage (24-36 months), it is expected that these children depend predominantly on family diets to meet their nutritional needs. We thus constructed variables for children 24-36 months as whether or not the child was being breastfed and, for comparative purposes measuring dietary diversity in exclusively non-breastfed children in this older category, minimum meal frequency and intake of minimum acceptable diet. For this age group, a minimum daily meal frequency of four was assigned to nonbreastfed children. WHO (2008) has recommended a minimum meal frequency of four times per day for nonbreastfed children 6-23 months and this was equally applied to this age group as a minimum. It is assumed that a separate variable for nonbreastfed children older than two years would better capture their feeding practices, as there is no compelling scientific basis for recommending breastfeeding beyond the age of 24 months nor are there clear cut recommendations for the optimal number of meals of for this age group (Sawadogo et al. 2006). This assumption also considers the findings of some studies that indicate that dietary diversity correlates more strongly with child growth among nonbreastfed children in some countries (Arimond and Ruel 2004).

Access to Water and Toilet Facilities, Problems Accessing Health Care, Child Receiving Vitamin A, and Child-Based Characteristics

Access to water and toilet facilities were considered in this study. Availability of healthcare was measured by whether a mother considers distance to health services as an important constraint as well as whether the child was reached with essential vaccinations and Vitamin A supplements. Child related variables such as the age, sex, and birth order known to influence the level of care children receive from their care givers.

Testing for the Endogeneity of Potentially Endogenous Variables

Table 1 lists variables or determinants for child and maternal malnutrition. Following previous studies on determinants of child malnutrition (Garrett and Ruel 1999; Smith et al. 2003; Smith, Ruel, and Ndiaye 2004), the range of independent variables has been classified as socioeconomic and proximal determinants of malnutrition. The socioeconomic determinants represent the resources necessary for achieving food security, supporting childcare, and a healthy environment. They broadly include child, maternal, and household characteristics. For this analysis, they include household economic status, household demographic structure such as presence of small children, gender of household head, maternal education and literacy level, and location that reflects differences between rural and urban dwellers across geopolitical and agroecological zones. Child characteristics include age, sex, and birth order.

The proximal determinants are closely related to the biological functions of both mothers and children or specific maternal practices related to food intake, health, and care giving. They include mother's nutritional status, prenatal and birthing care for mothers, and caring practices for children. While these proximal variables are recognized as important determinants of nutrition, concerns for endogeneity have limited efforts to estimate their independent impact in models that include socioeconomic determinants. Proximal determinants could be endogenous to the model as they may be determined by a set of factors that also determine the outcome (height-for-age). For example, maternal education and household socioeconomic factors may influence both feeding practices and children's height-for-age. Thus, including them would lead to biased estimation of the regression coefficients of the socioeconomic determinants because they are themselves the pathways through which socioeconomic determinants influence child nutrition (Smith, Ruel, and Ndiaye 2004).

As earlier elaborated (Garrett and Ruel 1999) in the nutrition production function, nutrition for an individual is conceived as the output of a production function in which a specific technology translates inputs into nutritional outcomes as represented by standardized anthropometric measures such as height-for-age. A proper estimating equation (nutrition production function) including both socioeconomic and proximal determinants would necessitate data on children's intake, including nutrients derived from breast milk consumption and long-term measures of morbidity, both of which various authors have indicated are not available in the DHS data. Also, such an analysis would also need to properly address problems of endogeneity of proximal determinants using suitable statistical modeling techniques (Ruel and Menon 2002; Smith, Ruel, and Ndiaye 2004).

One common approach to address the issue of endogeneity is the use of instrumental variables (using predicted as opposed to observed values of a variable) and two stage least squares methods (Garrett and Ruel 1999; Smith and Haddad 2000; Ruel and Menon 2002; Charmarbagwala et al. 2005). To use this method, it is necessary to identify at least one variable or determinant that is associated with the endogenous variable being predicted in the first stage of the equation (for example feeding practices), but is not associated with the outcome (height-for-age Z-score). Some past studies include only the socioeconomic determinants in OLS regression models because of the concerns for endogeneity associated with the proximal determinants and the lack of appropriate data to effectively estimate a 'nutrition production function' (Smith and Haddad 2000; Smith et al. 2003; Smith, Ruel, and Ndiaye 2004) citing that none of the variables available in the DHS datasets meet this criterion. Thus, they limited the regression models to the socioeconomic determinants for region fixed models to estimate reduced form equations for the dependent variables (height-for-age Z-scores (HAZ) and Body Mass Index (BMI)).

However, there are some recent studies that tested the endogeneity of some of the proximal determinants such as antenatal care using as instrumental variables assets and parental education that could be obtained in the DHS data (Umanna 2007). Although an earlier study (Grossman and Joyce 1990) using a Wu test, did not find evidence that antenatal care should be treated as endogenous, Ummana (2007) considered antenatal care as potentially endogenous as a health input that may be correlated with the error term in a child health production function citing that antenatal care-seeking and unobservable individual characteristics of mothers affect their behavior and also affect the health outcome of interest. In this context, for example, more concerned women may demand more antenatal care and, in other ways, behave to improve the health of their children.

The paper did an endogeneity test, F-test, and Hausman J test using variables like distance to healthcare centers, income related variables such as whether the household has electricity, owns agricultural land, owns livestock, or owns a bicycle and parents' education dummy variables (incomplete primary, primary, incomplete secondary, secondary, and higher), and whether the woman is allowed to have money set aside as instrumental variables. However, using the three tests, the education variables showed that antenatal care was endogenous ($p=0.000$), thus rejecting the null hypothesis of non-endogeneity. The education variables also passed the F-test of relevance of the instruments ($p=0.000$) and also passed the test of non-endogeneity of the instruments ($p=0.814$) thus the null hypothesis that the instruments are exogenous and valid and do not correlate with the error term could not be rejected and a two stage least squares (2SLS) regression model was used.

For this paper, efforts were made to test for the endogeneity of some of the variables as well as to test for the relevance of the instruments and how exogenous they are to improve the credibility of the Durbin-Wu-Hausman test of endogeneity. The results of the tests are summarized in Table 3. From the list of proximal variables specified, a few were selected for testing which represent the key concepts relevant to child nutrition. We also attempted to find some instruments within the dataset to test for their endogeneity knowing the challenge of identifying appropriate instruments within the DHS dataset. Potentially endogenous and proximal variables that were tested include Body Mass Index (maternal physical health and nutritional status), antenatal care (use of preventive health services), duration of breastfeeding, whether child was given minimum acceptable

diet, dietary diversity score as a measure of quality of complementary feeds given to children (infant feeding practices), and a child having BCG vaccine (availability of health service as well as health seeking behavior). Instruments for these variables were selected based on literature review, theory, and intuitive selection (Ummana 2007; Ajakaiye and Mwambu 2007; Smith and Haddad 2000).

For BMI, age of woman was used as the instrument, and the endogeneity of BMI was confirmed with the instrument passing the relevance test. A test of exogeneity of instruments and the over identification test could not be confirmed as only one instrument was involved. The result indicates the need for a two stage least square regression in a model that includes BMI as an explanatory variable. Contrary to findings from Umanna (2007), the endogeneity of antenatal care was not confirmed using a set of instruments that passed the test of relevance and exogeneity. Thus, the antenatal care variable tested (number of antenatal visits) was included as an exogenous variable in an OLS regression model. The instruments for duration of breast feeding and dietary diversity of complementary feeds did not pass the relevance test and thus were not included. Although the Wu test indicated the endogeneity of the variable of whether a child was given a minimum acceptable diet, the instruments did not pass the joint test of relevance. Joint test of instruments of BCG vaccine did not confirm the endogeneity of this variable, thus it was included in the final estimation model.

Although a 2SLS model was estimated in the course of the tests where BMI was identified as the significant variable with higher coefficients than in the OLS model, the credibility of the Durbin-Wu-Hausman test is best confirmed when the instruments are tested for both relevance and over identification or exogeneity (Davidson and Mackinnon1993; Smith and Haddad 2000). The test of over-identification helps to determine whether the instruments directly affect the dependent variable other than through the potentially endogenous variable to be instrumented. This could not be ascertained for age of mother, the instrument variable used for BMI, as the test of over-identification could not be performed for only one instrument. Thus to avoid any bias in estimates due to the effect of instruments not certified to be contemporaneously exogenous, BMI was not included in the final model for child analysis. Since the joint tests of relevance and exogeneity of instruments used for antenatal visit and receiving BCG vaccines were passed, these two proximate variables were included in the final model. Thus, the OLS regression was considered consistent and used in estimating the final models.

To analyze for all other proximal determinants, their levels and that of the socioeconomic determinants were compared across rural and urban areas of the geopolitical and agroecological zones, employing tests for significant differences across the areas. Where the measure of the determinant is continuous, a t test for difference of means was employed while for a dichotomous determinant, a test for differences in proportions (chi square distributed) was employed (Smith, Ruel, and Ndiaye 2004). Given the two-stage sample design of the DHS surveys where more than one household is sampled for each cluster, the possibility arises that the error term will not be independently and identically distributed. Thus, unobserved cluster–specific attributes may influence outcome variables similarly for households living in the same cluster, leading to biased estimates of the parameter covariance matrix. In this case, the option of a robust covariance matrix was used to compute standard errors and by extension t-statistics.

Chow's F Test for Parameter Stability

F-tests for parameter stability were performed to determine whether there are significant differences in the parameter estimates for main dependent variables in the child and woman models across the geopolitical regions, agroecological zones, and across rural urban locations. The hypothesis that the slope coefficients across the regions, agroecologcal zones, and rural urban locations are identical was rejected consistently as indicated by the F-statistics for both the child and women models (Table 7). For the geopolitical regions based on the child model, the test yields an F-statistic of 22.41 (p=0.000) and for the women model, 1462.2 (p=0.000). For the agroecological zones, based on the child model, the test yields an F-statistic of 32.33 (p=0.000) and for the women model, 1798.0 (p=0.000). The results for rural-urban locations are also presented in Table 7. These procedures have been used in various studies including those that used DHS data sets (Garret and Ruel 1999; Smith et al. 2003; Smith, Ruel, and Ndiaye 2004). The results give strong evidence of differences in the determinants, their strengths, or both across the regions, zones, and locations. The rest of the study thus undertakes regression analyses for each of the regions, zones, and locations separately (Smith et al. 2003; Smith, Ruel, and Ndiaye 2004). However, since the results did not indicate significant differences among the three southern regions (South East, South, and South West), and given that they may generally share similar geographical and other characteristics that distinguishes them from the northern regions, they are combined to form one South region in subsequent multivariate analyses.

Results

Descriptive Statistics for Children and Women

Table 4 shows marked variations in the prevalence of stunting among children and chronic energy deficiency among women of reproductive age by regions, agroecological zones, and rural-urban locations. Incidence of stunting is higher both in terms of extent and magnitude in rural areas than in urban ones, highest in the North West (51 percent) followed by the North East (35.5 percent), and higher in the Sudano-Sahelian and Guinea savannahs compared to the savannah and the humid forest zones. This trend is confirmed by past and recent national studies (NPC/ORC Macro 2004; Maziya-Dixon et al. 2004; NPC/ICF Macro 2009). Generally, these prevalence rates are among the highest in the world and explain why Nigeria is classified among the 20 countries with the highest burden of malnutrition in the world (Black et al. 2008; Bryce et al. 2008).

The prevalence rate in the North West compares to the rates in other countries as Afghanistan (53.7 percent) and Yemen (53.1 percent) (Black et al. 2008a). Similarly, the rate of stunting in the Sudano Sahelian zone exceeds the rates in countries like Ethiopia (46.5 percent), Sudan (43.3 percent), Madagascar (47.7 percent), and India (48 percent). Based on maternal Body Mass Index that indicates chronic energy deficiency or thinness among women (when BMI is less than 18.5), there are more thin women in the rural areas, North East and North West and in the Sudano Sahelian and Guinea savannahs than in other regions and agroecological zones. Incidentally, while North Central records a significantly lowest level of maternal thinness (7 percent), South West has over twice the prevalence of thinness among women than North Central and the highest rate in southern Nigeria.

Child and maternal malnutrition are associated with high mortality risk, considerable human suffering, lowered resistance to infections, lowered economic productivity, and lost intellectual resources (Micronutrient Initiative/UNICEF 2004). Poor nutritional status has been attributed to a combination of factors that include inadequate macro- and micro-nutrient intake, poor caring capacities and practices, poor health care, and inadequate sanitation and hygiene.

Descriptive Statistics Relating Height-for-age and Maternal Body Mass Index to Proximate and Socioeconomic Determinants of Malnutrition

Table 5 shows the mean height-for-age Z-scores for different categories of the determinants of child malnutrition. Mean height-for-age is substantially lower in the North West, North East, and North Central compared to levels in the southern regions. While in other regions, mean height-for-age Z-scores are lower in the rural areas compared to the urban areas, in the North East, mean height-for-age Z-scores are substantially lower in the urban than in the rural areas. Generally, similar trends apply with regard to agroecological zones with mean height-for-age Z-scores being lower in the Sudano Sahelian and Guinea savannahs than in other zones. Mean height-for-age Z-scores are lower, as expected, among the poorer and poorest households, children of mothers with limited or no education, mothers who are chronically energy deficient, among boys than girls, and among those mothers who do not at least make up to four antenatal care visits during pregnancy. Mean height-for-age Z-scores appear consistently higher in children from female-headed households, somewhat, contrary to expectations, though over 80 percent of households in Nigeria have male household heads. Mean height-for-age Z-scores are substantially lower among children with household heads that are primarily involved with agriculture.

Mean height-for-age also appears higher when households use safe water and flush toilets as opposed to using unprotected water and having no latrine or using other less sanitary toilet facilities. Initiating breastfeeding within one hour of birth, delivering babies in medical facilities, and receiving BCG vaccinations are also associated with higher mean height-for-age Z-scores.

To evaluate the adequacy of complementary foods, we used the following age specific indicators: dietary diversity, meal frequency, and minimum acceptable diet as a sum of minimum dietary diversity and meal frequency for the age groups of 6-11, 12-23, and 24-36 months. For the comparisons of means of height-for-age z-scores by dietary practices for children 24-26 months, we only used the sample of nonbreastfed children, who constitute about 70 percent of all children in this age group (Table 5). In both the rural and urban areas of the geopolitical regions, meeting the minimum food frequencies is associated with better nutritional status across all the age groups, with urban children having higher height-for-age Z-scores compared to their rural counterparts.

A minimum dietary diversity of at least four food groups a day is generally associated with better nutritional status generally among children in all the age groups. However along specific rural urban divides, meeting the minimum dietary diversity is associated with better growth among urban rather than rural children 6-11 and 12-23 months, while for children 24-36 months, meeting the minimum dietary diversity is associated with higher height-for-age Z-scores in both rural and urban areas of the regions. Children fed the minimum acceptable diet have higher height-for-age Z-scores generally across all the age groups and in rural and urban areas of each region, except specifically in the

rural areas for children 6-11 months. The predominance of breastfeeding (over 96 percent) in this age group may explain this finding.

Arimond and Ruel (2004) reported similar findings where the interaction between diversity and child age group showed that diversity was most strongly associated with height-for-age Z-scores among older children in some countries (e.g., Peru), whereas the opposite was true in Rwanda, where the strongest association was among children 6-11 months old. Urban-rural differences in the association between dietary diversity and height-for-age Z-scores were also observed in Haiti and Mali, with stronger associations in urban areas in Haiti and stronger associations in rural areas in Mali. Results of the Spearman ranking correlations (not shown) of height-for-age Z-score with dietary diversity did not show significant association for children 6-11 months but did for children 12-23 months (r=0.1; p=0.04) and nonbreastfed children 24-36 months (r=0.1; p=0.07). Meeting minimum feeding frequencies for their ages is significantly associated with increased height-for-age Z-scores across all the age groups at 1 percent level with a correlation coefficient of 0.1. While having minimum acceptable diet is not significantly associated with child growth in children 6-11 months, it is associated with increased height-for-age Z-scores in age group 12-23 months (r=0.1; p=0.03) and in nonbreastfed children 24-36 months (r=0.2; p=0.0000).

Table 6 shows Body Mass Index is highest (23.00) among women in the North Central and lowest among rural women in the North West (21.00). By agroecological zones, mean maternal BMI is higher in the humid forest zone. It also shows that the richer the household, the higher the BMI. This is also the pattern with maternal education. Incidentally, women in female-headed households have better nutritional status than when in male headed households and women with household heads that are primarily engaged in agriculture are thinner. Having access to or using safe water, using a flush toilet, being literate, deciding alone on earned income, and working to earn income are significantly associated with improved maternal nutrition. Women who find distance as some challenge to accessing healthcare are more likely to be malnourished. Tables 8-11 present the differences in the levels of socioeconomic and proximate determinants of child and maternal malnutrition. These levels are referred to and discussed in the discussion and other relevant aspects of the paper.

Multivariate Analysis: Results and Discussions

Household economic status, household head work in agriculture, and woman's work for income

The economic status of a household is an indicator of access to adequate food supplies, use of health services, availability of improved water sources, and sanitation facilities which are prime determinants of child and maternal nutritional status (UNICEF 1990; Girma and Genebo 2002). More resources available to a household should translate into higher expenditures on food and health and result in improved nutrition (Charmarbagwala et al. 2005). The results indicate that generally, across rural and urban areas, household economic status has significant and positive effect on child nutrition, though with very limited effect (Tables 12 and 13). The results are also presented in summary tables of significant determinants (Tables 20 and 21).

Household economic status is found to have statistically significant and positive effect in rural North East and South regions, and in urban areas of the North East, North West,

and in the South region. A unit increase in household wealth index is associated with only about 0.0002 to 0.0006 increases in height-for-age Z-scores across the rural and urban areas of the regions. Across the agroecological zones, economic status is found to have similar level of effects in Sudano-Sahelian savannah and the humid forest zone (Table 14, 15, 20, and 21). No significant effect is observed for the rural and urban areas of other regions. This result is interesting as the level of widespread poverty across regions as well as regional differences in the prevalence of poverty and between urban and rural areas would have prompted some expectation of stronger household economic status effect.

Similarly for the mother, generally in the rural and urban areas, household economic status had positive and significant but weak effect on maternal nutrition (Tables 16, 17, 22, and 23). At the regional level, it has similar level of effect in the rural North Central and South regions, and in all the urban regions excepting North East. At the agroecological level, it exerted a similar level of effect, however, consistently across all the rural and urban areas of the agroecological zones.

There are indications that a positive but weak relationship of income and child growth is consistent with findings of other studies in Africa and though, increases in the amount of income available per person are a necessary but not sufficient condition for reducing poverty, higher incomes over time should improve nutritional outcomes (Penders, Staazt, and Tefft 1999; Smith and Haddad 2000). The consistency and wide reach of the effect of household economic status may indicate its relative importance to child and maternal nutrition. Covering both rural and urban areas may maximize the effect of programs designed to improve household economic status to enhance both child and maternal nutrition.

This paper also explored the independent effect of household heads working in the agriculture sector as well as women's work for cash income. Almost all of the household heads have occupations and classifying them as primarily involved with agriculture or not is considered more useful in understanding the impact of their occupation on maternal and child nutrition. Being involved with agriculture means generally being a farmer and includes those involved, though in substantially limited proportions, in fishing, farm labor, and forestry activities. The occupation of the household head represents an important resource for the well-being of household members. The impact of the household head being primarily involved in agriculture is linked to the notion that poverty rates, hunger, and malnutrition are higher in the rural areas and among folks that depend primarily on agriculture for their livelihoods (Southgate 2007; NBS 2005). Table 2 shows the link between working in agriculture and poverty, thus, raising concerns about the nutritional well-being of children in a country where over 60 percent of its population depend on agriculture.

Descriptive statistics show low height-for-age to be consistently and significantly associated with household head being primarily involved in agriculture except in urban areas (Table 4). The multivariate results amply indicate that the negative effect of household heads being primarily engaged with agriculture on child growth is particularly a rural phenomenon, in the North Central and South regions and the humid forest zone located also in the South (Tables 12-15, 20, and 21). It was not found to have significant effect in the rural and urban areas of the North East and North West that are key agricultural production and marketing zones and a positive and significant effect was found, in urban Sudano-Sahelian savannah.

Table 8 shows that over 50 percent of household heads are involved primarily with agriculture in the rural northern regions compared to the less than 30 percent rural south regions excepting southwestern Nigeria where the rural farming population is also above 50 percent. The 2005 report on the poverty profile of Nigeria indicated about 26 percent involvement in agriculture for the North Central region with Benue State, a core agricultural North Central state having about 47 percent of households involved with agriculture. The little or no impact in urban areas may be understandable as a substantially lower proportion of household heads are involved in agriculture in the urban areas of the regions having less than 12 percent of farmers in most parts, excepting in South East where close to forty percent of households in the urban areas are involved with agriculture (Table 9). The National Bureau of Statistics had stated that only 14 percent of farmers reside in the urban areas (NBS 2005).

The results also suggest that the mechanism for the impact of primary engagement with agriculture on child growth could be through the known impact of poverty on child growth as poor households are said to be more involved in agricultural occupations (NBS 2005; Mogues et al. 2008). Studies that have explored the effect of agriculture on nutrition have indicated the income effect amongst other factors (Penders, Staatz, and Tefft 1999). The DHS 2003 data reveal that the majority of men in agriculture (about 53 percent) state that they are not paid for their work (ORC/Macro 2004) and our results indicate that 42.3 and 33 percent of household heads working primarily in agriculture belong to the poorest and poor wealth categories. NBS (2005) has reported that 26.3 percent of household heads involved with agriculture and who reside in the rural areas are 'core poor'. However, in testing for the income effect, removing the variable on work of household head in agriculture in the models did not improve the estimated independent effect of household wealth on child growth.

The positive and significant effect found in urban Sudano-Sahelian savannah may not be unconnected with the situation where key farmers are also involved in major domestic and cross border food marketing activities in the urban areas as there is a presence of major food markets in this zone enhanced by better communication facilities and market information systems that result in higher proceeds from agricultural activities (Aker 2009). The effect of household heads engagement in agriculture on maternal nutrition is indicated only in rural North Central (Tables 16, 22, and 23), where women in such households are likely to get thinner.

Another factor that relates to wealth or income occurs when the mother is working to generate income as most of the mothers who work indicated being paid for their work. Literature suggests that income earned by women or expenditure controlled by them may have a greater propensity to be used to benefit child health and nutrition than men's income (Charmarbagwala 2005). Descriptive statistics consistently showed better mean height-for-age Z-scores associated with mothers working to earn income (Table 5). Having controlled for household wealth, the independent effect of mother's work to earn income on child nutrition is established. This maternal work status is found to have a positive effect on height-for-age generally in rural areas, and specifically in rural North Central and North West (Tables 12, 13, 20, and 21). It is interesting to note that this maternal work status is associated with significant and positive impact on child growth in regions with high levels of malnutrition (especially North West) and substantially lower percents of women working to earn income (Table 8). Percent of women working is as high as 93 in South West and as low as 54 percent in rural North West. Our results show that more women in rural areas work for income than in urban areas (Table 9), except in

the South East. Mother's work status has no significant effect on child growth in the urban areas.

By agroecological zones, maternal work status is found to have significant and positive effect in rural Sudano-Sahelian and Guinea savannahs and in urban humid forest zones. In these agroecological zones, women who work for income are 54 and 52 percent respectively compared to 86 percent in derived savannah and 68 percent in rural humid forest zones where maternal work status was not significant (Tables 10 and 11).

This study has revealed that allowing mothers to work to earn their own income would substantially contribute to the reduction of child malnutrition in the regions and zones that have the highest burden of malnutrition in the country (especially North West and Sudano-Sahelian savannah). When women earn income, it increases their status, feeling of self worth and confidence, and affords them some autonomy and recognition in decisionmaking (Smith et al. 2003; Garrett, Bassett, and Marini 2009). Additionally, income earned by women is, to a much greater extent than men's, ploughed back into family well-being expenditures. Thus, women's modest, yet frequent income, affects income elasticities of demand for family consumables (including basic services) more directly than men's incomes (Schuftan, der Bruegge, and Chirmulay 1998).

Some studies have indicated negative impact of maternal work on child nutrition in Africa by reducing time available for household activities related to child development (Glick and Sahn 1998; Genebo 2002). However, Penders, Staazt, and Tefft (1999), while recognizing the potential negative impact of maternal work on child nutrition in Mali, indicated the possibility of using raised incomes to offset the negative impacts. Smith et al. (2003) had warned that increase in the status of women, which earning her own income contributes to, could have negative effects upon infant feeding practices if deliberate steps are not taken to protect these practices (Smith et al. 2003).

The effect of maternal work on her nutritional wellbeing (measured using the Body Mass Index) is high, positive, and significant in rural areas generally, and specifically, in rural North East and the South region and in rural Guinea Savannah (Tables 16-19 and 22-23). No significant effects are indicated in the urban areas of the regions and agroecological zones.

The Effect of Maternal Knowledge (Education and Literacy)

Education is one of the most important resources that enable women to provide appropriate care for their children, which is an important determinant of children's growth and development (Engle, Menon, and Haddad 1997). There is considerable evidence across countries that the nutritional status of children varies directly with the level of education of their parents, and in particular, their mothers (Benson 2004). Maternal education, as part of parental education, influences child nutrition outcomes through the effect of higher incomes and better use of available information about child health and nutrition (Garrett and Ruel 1999; Smith, Ruel, and Ndiaye 2004; Charmarwabagwala et al. 2005).

Generally, in the rural areas, maternal education, including having primary and secondary education, did not indicate any significant effects on child nutrition. At the regional level, no significant effect was indicated in the rural areas (Tables 12, 13, 20, and 21). Maternal reading literacy also had no significant effect in the rural regions.

However, in the urban areas, having both primary and secondary education is positively associated with child growth especially in the North Central, North East, and North West. Generally in the urban areas, a child of a woman with primary education has a height-for-age 0.41 Z-score higher than the child of a woman with no education. The increase for a child whose mother has a secondary education is substantially higher than that for primary education at 0.54 (Table 13). Compared to a child whose mothers have no education, a child of a woman with primary education has higher height-for-age Z-score of 1.1 in urban North Central and 1.3 in urban North West. Where the mother has secondary education, the increases in Z-scores are 0.76 in urban North East and 1.15 in North West. By the agroecological zones, having secondary school education was associated, however, with increase of 0.69 height-for-age Z-scores in rural Guinea Savannah, and in urban Sudano-Sahelian savannah a strong and positive effect is indicated (Table 15).

For the mother, having secondary education has a significant and positive effect on her BMI in rural North East. Being literate is associated with improved maternal nutrition in rural areas generally, and specifically in rural North East and North West. In the urban regions, having primary and secondary education has significant effects on her BMI in the urban North Central region.

The universality and the very high level of education in the southern regions may explain the insignificant effect of education on child growth in these regions, given the disproportionate difference in the level of education between northern and southern regions. Table 8 shows that 77 and 81 percent of mothers in rural North East and North West respectively have no education compared to 11 and 9 percent in rural South East and South South. Also in terms of reading literacy, while about 80 percent of women in South East are literate, only about 14 percent are in rural North West. Similar patterns are observed in the urban regions though the level of education and literacy is generally high in the urban areas (Table 9).

While investing in women's education is widely advocated as a key intervention strategy for promoting child health and nutrition, the effects of maternal education on children's nutritional status remain controversial in the literature (Caldwell 1979; Smith et al. 2003). One would expect to see a 'sweeping effect' of maternal education on child growth, especially in the rural areas. Surprisingly, having primary education was negatively associated with child growth (Table 14) in rural Sudano-Sahelian and derived savannah. Maternal reading literacy did not indicate any significant effect on child growth in both rural and urban areas of the agroecological zones except for a negative but significant effect in rural Guinea savannah. And given the sharp differences in the level of education of mothers between the northern and southern regions (Tables 8-11) and the generally higher prevalence of malnutrition in the rural areas, it is surprising to note the insignificant effect of both maternal education and female literacy across the regions, especially in the rural northern regions.

The lack of effect and even negative impact of education and literacy on child growth in the rural northern regions and agroecological zones raises concerns about the very low level of maternal education, quality of education and the need for some alternate measures to improve maternal knowledge and awareness in such settings. Similar surprises have been indicated in other studies reported in a meta-analysis by Charmarwabagwala et al. (2005), who also reported that female education and literacy are nearly always insignificant in West Africa compared to East and Southern Africa and

Latin America. There are also indications that when maternal health knowledge is imparted outside the formal educational system and understood by the less educated, then the effect of education will be removed (Glewwe 1999). The negative impact of education on child nutrition could also result when educated mothers take up paid jobs outside home without adequate arrangement for child care (Emina et al. 2006). Our results indicate that 73 percent of women who work away from home are educated and about 68 percent of them take care of their youngest children by themselves or through some older relative or their spouse, who are considered better caregivers than young siblings especially where patronage of institutional care is relatively low. However, Igbal and Ahmed (2009) explained that some nonlinearities and also a threshold exist in the relationship of maternal education and child health in Nigeria. With height-for-age Z-score as a proxy for long-run child health capital, regression results reveal that there is hardly any significant effect of mother's education on child health if mothers do not go past primary education.

In further analyzing the causal impact of maternal education on other human-capital aspects of child development, Behrman and Rosenzweig (2002) and Plug (2004) find that more schooling for the mother, in a developed-country context does not lead to more schooling for the child, after controlling for genetic endowment and assortative mating. Grossman (2006), however, states that given these rather surprising results, which contrast with findings from many previous studies, these findings should not be treated as definitive. This may be particularly true in a developing-country context where school choice and school quality is more limited, and so maternal education might be expected to still have a greater effect.

Female-Headed Households, Age of Mother, and Household Head Decision on Earned Income

The impact of female headship on household well-being is said to operate through contradictory direct and indirect channels (Charmarbagwala et al. 2005). When women head households, they have greater say in decisionmaking and thus tend to have better nutritional indicators. On the other hand, because female-headed households tend to have limited resources, worse nutritional status is likely. This study does not indicate any significant effect of female headship on both maternal and child malnutrition (Tables 12-23). A comparative review of studies on female headship and nutrition across West Africa and other regions showed that because West African women usually have greater control over income than is the norm elsewhere, female-headed households do not have better child nutrition outcomes than male headed households on the average (Charmarbagwala et al. 2005). A study in Borno State in the North Eastern region indicated a positive relationship between female headship and household food security (Amaza, Adejobi, and Fregene 2008), which may not necessarily translate to improved nutrition outcome. Additionally, the incidence of female headship is generally low in the North, lowest in the North East with less than 7 percent, and over 20 percent in the three southern regions (NDHS 2003).

If employed women do not have control over their income and decisionmaking authority within the household, they are deprived of the ability to take actions that will benefit their own wellbeing and also their children’s. Studies have shown that, at similar levels of income, households in which women have a greater control over their income are more likely to be food secure (Kennedy and Haddad 1991). Our results that show mother deciding alone on earned income have a positive and significant effect on child growth in

rural Sudano-Sahelian zone. Also interestingly, mother working to earn income is found to also have a significant positive effect on child growth in this zone. These results are interesting to note for a zone that has the highest prevalence of stunting (48 percent) compared to other agroecological zones (Table 4). Incidentally, this zone also has the highest proportion of mothers deciding alone on earned income (86 percent, Table 10). A negative effect is reported for rural Guinea savannah, however, and no significant effects are reported for other rural and urban regions. A negative effect is similarly observed on maternal BMI in rural North East. The fact that generally, a high proportion of Nigerian women (over 70 percent) decide alone on their earnings (NPC/ORC Macro 2004) and the earlier indication that West African women usually have greater control over income than is the norm elsewhere, may explain why there is a lack of significant effect of this variable on child nutrition.

Woman having the final say on her health, a simple measure of women's status in the household, has significant and positive effect on her BMI in rural areas generally, and in rural derived savannah (Tables 16-19 and 22-23). It does not have any significant effect on maternal nutrition in the urban areas of the geopolitical regions and agroecological zones.

Age of household head reflects maturity and capability to provide and meet household needs. The significant effect of age of household head on child nutrition is not indicated across rural and urban areas of the region except in the urban humid forest where every increase in age in years of the household head results in decrease in height-for-age Z-scores by 0.023 (Tables 15, 20, and 21). The mean age of household heads is 42.5 years in both urban humid and derived savannahs, higher than the mean age of households in the other zones (Table 11). However, for the mother, every increase in years of household head is associated with 0.015 increases in Body Mass Index generally in the rural areas, increase in BMI of 0.041 in the rural South Region, and increase of 0.038 in the rural humid forest. Interestingly, though not clear how it works, just as is the case for child malnutrition, the yearly increase in age of household head impacts negatively on the mother in the urban Humid Forest.

A probably non-linear relationship has been reported between age of mother and child health outcomes, with higher risks for both older and younger women (Charmarwabagwala et al. 2005). Every increase in age of mother in years is associated with increase in height-for-age Z-scores by 0.040 generally in rural areas, by 0.044 in rural North Central, 0.078 in rural North East, and by 0.061 in rural Guinea savannah (Tables 16-23). Also in the urban areas, height-for-age Z-scores increases even more than in rural areas with every additional year of age of the mother adding 0.12 in urban areas generally, and specifically by 0.13 in urban North East and 0.11 in the South Regions. No significant effect on child growth is indicated for the urban areas.

The effect of maternal age on BMI is also positive and significant generally across rural and urban areas, then specifically in rural North West and Sudano-Sahelian savannah as well as in urban North East, the South regions, and across all the agroecologcal zones except the Guinea savannah (Tables 16-23). Mean age of mothers in rural North Central and North East is 28 years compared to 30 years in South East and South West. Age of marriage is generally lower in the northern regions where teenage pregnancy or motherhood is usually high. Raising the age of marriage, which tends to occur as part of demographic transition, directly reduces child health risks, and affects nutrition positively (Charmarwabagwala et al. 2005). In the urban areas, it improves by 0.13 in the North

East and 0.17 in the South West. Across rural areas of the agroecological zones, a significant positive effect is indicated only in the rural Sudano-Sahelian zone (0.06). While in the urban areas of the agroecological zones, maternal BMI improves for every additional increase in age of mother by 0.11 in Sudano-Sahelian savannah, derived savannah and in the humid forest zone. Age at first birth has a significant negative effect on maternal nutrition in rural North West, and no significant effect on maternal nutrition across urban areas of the geopolitical zones. It also has no significant effect across rural and urban areas of the agroecological zones.

Household Size, Percent of Children Under Five, Child-Based Determinants (Age, Sex, and Birth Order), and Parity

The effect of household size on nutrition outcomes could be varied (Mukherjee and Benson 2003; Garrett and Ruel 1999; Charmarwabagwala et al. 2005). If a household is large because it comprises a large number of able bodied persons of working age, then partly by virtue of economies of scales, this could translate to improved welfare of household members, thus resulting in improved nutrition. But where there are many young children, they compete for resources and children of higher birth order become particularly vulnerable.

Household size (both in the direct and transformed or squared form) has no significant effect on child nutrition across the rural areas of the geopolitical regions. In the urban areas of the regions, significant positive effects are indicated in North Central and South Region (Table 13 and 22). Table 9 shows that mean household size in urban areas is 7.5 in North Central, 8.7 in North East, and 5.6 in the South West. While the reasons for this positive effect of increasing household size may not be clear, there are indications that when large families comprise productive adults, their presence and contributions may result in improved welfare for household members. Similar positive effects are indicated in rural derived savannah and urban humid forest. The squared household size, however, consistently indicated a negative association with child nutrition in urban North Central, the South Region and humid forest showing how child nutrition deteriorates over time as household size increases.

For the mother, no household size effect is indicated across the rural areas of the regions and in the urban areas a significant negative association is found where every unit increase in household size is associated with reduction in BMI by 0.12 points in urban North Central. No significant effects are indicated in rural and urban areas of the agroecological zones. The effect of parity on maternal nutrition was significant and positive in rural areas in general, but has a high negative effect on maternal nutrition in the rural North East particularly (Table 16). No significant effect is indicated across other rural and urban regions across the agroecological zones. Some studies have associated increased parity with low maternal BMI (Girma and Genebo 2002).

Sometimes what matters more is the percentage of children under five of the total household size. This is because very young children more or less act as consumers of scarce household resources in terms of financial or nutritional resources, or parental time, and thus their percentage reflects the burden of care they exert on the household and particularly, the mother as the primary care giver. The effect of this factor on child nutrition is significant and expectedly negative only in the rural Guinea savannah. Every percentage increase in households of children under five would lead to reduction in height-for-age Z-scores by 0.023 in this savannah (Table 18).

This factor appears to have effect on the nutrition of the mother across more regions than of the child. A percent increase of children under five in the family reduces a woman's BMI by 0.010 in rural areas generally, and by 0.04 in rural North Central, and 0.024 in rural North East (Tables 16, 22, and 23). By agroecological zone, a percent increase of children under five reduces maternal BMI by 0.023 in rural Guinea Savannah (Table 18). The results show that the effect of this factor on maternal nutrition appears significant only in rural northern regions and agroecological zones. Although Tables 8-11 show only slight differences in percentage of children under five across rural and urban regions and zones, the negative effects may also be reflecting the known burden of poorly spaced childbirths and care for young children on the health or nutritional well-being of the mother in rural northern agricultural areas (NPC/ORC Macro 2004).

The significant and negative effect of age of child on child nutritional status is almost universal, cutting across almost all rural and urban regions and agroecological zones (Tables 12-15 and 20-21) Nutritional status is found to deteriorate with age at a monthly rate of height-for-age Z-scores of 0.06 in North Central, 0.10 in North East, 0.09 in North West, and 0.05 in the southern region. This reflects the deterioration in rapid growth that typically occurs in young children (Garrett and Ruel, 1999; Smith, Ruel, and Ndiaye, 2004). Figure 2 shows that stunting rate is lowest when child is under 6 months, increases significantly after 6 months and peaks after the first year into the second year. A general deterioration in nutritional status when the protective effects of breastfeeding have waned, especially as children commence complementary feeding, can be observed. Although we have new evidence showing that children under six months are not as protected by breastfeeding as earlier thought (de Onis et al. 2008), the common concern remains that even with optimum breastfeeding, children will become stunted if they do not receive adequate quantity and quality of complementary foods after six months of age and substantial growth faltering is associated with this stage in child growth and development (Black et al. 2008). This emphasizes the need to pay attention to feeding, care and nurture of children 0-24 years, as they represent the critical window of opportunity to effectively address nutrition concerns, after which the negative impact of malnutrition becomes irreversible (Black et al. 2008).

Tables 8-11 show significant variations in infant feeding practices and the quality of soft, semi solid and solid foods given to children in the 6-11, 12-23, and 24-36 months age groups. Child feeding practices differed significantly across rural and urban locations in the geopolitical regions and agro ecological zones in terms of minimum dietary diversity, feeding frequency and meeting minimum acceptable diet standards for children 6-23 months especially. The mean daily dietary diversity hardly exceed 2.0 for breastfed children 6-11 months except in rural North Central and South East that have mean dietary diversity of 2.2 and 2.8 respectively. Urban children in this category have higher dietary diversity especially in the southern regions. Older children (12-36 months) expectedly have higher mean dietary diversity as they are required to depend less on breast milk. In the urban areas of the geopolitical regions, marked higher dietary diversity is observed generally across the regions, indicating better quality of complementary foods fed to children. A similar pattern is indicated across the rural and urban areas of the agro ecological zones, with higher dietary diversity in the humid forest zone. The World Health Organization has indicated that the minimum diversity in food fed to children 6-23 months is four groups daily and the minimum feeding frequency is at least thrice daily (WHO 2008). Households in southern regions and the derived and humid forest zones are more likely to meet these standards than households in the

North East and North West. In addition, households in the urban regions are more likely to meet this standard compared to households in the rural areas.

Meeting the twice daily minimum meal frequency for breastfeeding children 6-11 months and the thrice daily requirement for breastfeeding children 12-23 months and children 24-36 months (whether breastfeeding or not) was lowest for children in the 12-23 age group in the rural areas, and much lower in the three northern regions compared to the children in the southern regions. This may help explain why stunting prevalence is highest in this age group. The level of meeting the minimum feeding frequency of four times per day for nonbreastfed children in the 24-36 months group is generally low across the regions, with the lowest levels recorded for both rural and urban regions in North East and North West and in the Sudano Sahelian and Guinea savannahs. Fewer than 40 percent of children across all age groups and most of the rural and urban areas of the geopolitical regions and agro ecological zones receive the minimum acceptable diet, reflecting the generally poor infant and young child feeding practices in the country.

Consistently, the nutritional status of girls is better than that of boys in rural areas generally, and specifically in rural North Central by 0.42 Z-scores and 0.38 Z-scores in the South Region, 0.28 Z-scores in rural Guinea Savannah, and by 0.48 in rural derived savannah (Tables 12, 13, 20, and 21) Being a girl child did not affect nutritional status across the urban areas of the geopolitical and agroecological zones. Garret and Ruel (1999) and Agnihotri (1999) reported this positive effect of being a girl child with improved nutrition over the boys reflecting a yet not well understood greater vulnerability of boys at this stage. This finding contradicts the theory that the low priority of girls in many cultures would bias food consumption toward boys (Charmarbagwala 2005). It is, however, not clear why the sex effect is not significant in the urban areas. While a similar case of not significant sex effect in Asia in contrast with other regions was explained to indicate the presence of discrimination against females (Smith et al. 2003), the results may also suggest that the known fact that urban dwellers are more likely to have the resources and infrastructure to adequately take care of the boys as well as the girls may have reduced their vulnerabilities at this, thus making no difference in nutrition outcomes of children by sex. There are indications that discrimination against girls become manifest when resources are significantly limited in Nigeria (Ene-Obong, Enugu, and Uwaegbute 2001). Programs that improve the nutritional status of present male and female children through nutritional and educational inputs are likely to translate to better nutritional status of their own children in the long-term (Garrett, Bassett, and Marini 2009).

Antenatal Care, Vaccinations, Distance to Healthcare Challenges, Maternal Decisionmaking and Other Health Service Issues

Children of mothers who receive antenatal care are more likely to be healthy and survive than children whose mothers have no visits during pregnancy as they have a significantly high risk of stunting (Girma and Genebo 2002; Charmarbagwala 2005). The number of antenatal care visits that mothers make significantly and positively affects child nutrition generally in the rural areas and specifically in the South Region (Tables 12-13 and 20-21). No significant effect is recorded for the urban areas of the region. Also, across the rural and urban areas of the agroecological zones, no significant effect of antenatal care visits is indicated (Tables 14 and 15).

The mean number of antenatal visits differed significantly across the rural and urban areas of the geopolitical regions and agroecological zones (Tables 8-11). In the rural areas, the lowest mean number of visits is less than 2 in North East and North West compared to 7 in the South East and close to 9 in the South West. Ejembi et al. (2003) found the rate of non-utilization of antenatal services in the North West (65 percent) to be about 13 times as high as the rate in South Western Nigeria (4 percent). Although WHO recommends four visits, antenatal care service in Nigeria is still patterned after the traditional schedule that recommends monthly visits until 28 weeks of gestation, fortnightly visits until 36 weeks, and weekly thereafter until delivery (Fawole, Okunola, and Adekunle 2008). Thus, different studies provide a range of mean number of antenatal care visits such as mean number of visits of 4 with a range of 1-12 (Fawole, Okunola, and Adekunle 2008), 6.5 +-1.8 (Ibeh 2008), and median number of 6 with a range 1-20 (Nwakoby 2007).

Similarly, percent of women who had at least one antenatal visit compared to those who never had any is as low as 32 percent in the North West and as high as 84 percent in the South West. Among those who attend, the percentages of those who attend at least four times compared to those who did not meet this expected minimum attendance during the course of pregnancy (ORC Macro/NPC 2004) is as low as 54 percent in the North East and as high as 98 percent in the South West.

Despite these significant differences, its effect on child growth appeared limited, especially in the rural areas and the northern regions that have significantly lower attendance. This may be providing some indication of the importance of quality of services received when visits are made as defined by the caliber of healthcare providers that attend to them, amongst other factors. The 2003 DHS shows that while only 5.4 percent of mothers in the North West and 11 percent in the North East were attended to by doctors, over 50 percent of their counterparts were attended to by doctors in the South East and South West.

Having a basic vaccine such as BCG (Bacillus Calmette-Guerin) is found to have no significant effect across rural and urban areas of the geopolitical regions and agroecological zones except in rural Sudano-Sahelian savannah (Tables 12-15 and 20-21). In the rural Sudano-Sahelian zone, having BCG was associated with increase in height of age Z-score of 0.66. The strong positive effect indicated is expected as the zone has the lowest BCG vaccine rate at 17 percent, compared with 27.8 percent in Guinea savannah, 57 percent in derived savannah and 69 percent in humid forest. Other health service related factors such as percent of children ever vaccinated, women who give birth to children in medical facilities, children reached with vitamin A supplements show similar patterns (Tables 8-11). The BCG is usually administered at health facilities and having this vaccine may provide some indication of use of health services. In rural Sudano-Sahelian savannah, only 7 percent of women deliver at health facilities compared to 62 percent in humid forest and limited use of antenatal care predicts low BCG vaccination levels in the North (Babalola and Lawal 2009). Preliminary descriptive statistics show that low use of health services is significantly associated with low height-for-age (Table 5).

Distance being a substantial problem to accessing health services is found to have negative effect on maternal nutrition generally in the rural areas and specifically in the rural North West. (Tables 16-19 and 22-23).The Integrated Maternal and Newborn and Child Health Strategy has identified distance to health services as one of the three

critical factors that affect access to health services in Nigeria (FMOH 2007). Although the 2003 DHS did not provide data on estimated distance in kilometers, data on women's perception of distance as a hindrance was used. It has no significant effect on maternal nutrition in the urban areas of the geopolitical regions and agroecological zones. This may be understandable as most health services in urban areas are located within easy reach of people and access is also facilitated by relatively improved transport infrastructure compared to rural areas. A positive effect is indicated in urban derived savannah and for such effects it could be that these urban women have relatively high BMI and could also afford transport costs or afford themselves some convenient transport infrastructure despite their perception of distance as a challenge to accessing healthcare.

It has been observed that there are large regional, rural/urban, and income inequalities in health outcomes and in healthcare utilization in Nigeria (Donors Health Paper 2008). Although Nigeria has, on average, an adequate number of health facilities, their distribution is very unequal. Generally, health facilities appear disproportionately concentrated in the South than in the North and in the urban than in rural areas (FMOH 2007). This has important implications for the poor, rural, and agriculture dependent populations. Also low education, cultural, and religious barriers also limit access to health services as the NDHS 2003 (NPC/Macro ORC 2004) found that only 23 percent of married women have any final say in decisions concerning their own health care, 26 percent have a say in decisions concerning their children's health care, and more women in the North are less likely to have say on these issues. Cost considerations are also limiting with significant implications for the remotely located poorest of the poor populations.

Quality considerations also matter. About 71 percent of Nigerians have access to a PHC facility within a 5km radius of their homes but many of these centers are not functional due to lack of equipment, essential supplies, and qualified staff (FMOH 2007). Recent studies implicated distance and availability of quality service in the substantial movements of malnourished Nigerian children in extreme northern parts of the Sudano – Sahelian savannah to therapeutic feeding and health centers in neighboring Republic of Niger (FMOH, SC UK, UNICEF, and FEWS NET 2007, 2008). To overcome physical barriers, GoN needs to ensure that health facilities are sited in rational ways, matching the catchment population, and that they are supplemented by outreach services by Community Health Extension Workers, while cultural barriers can only be overcome through education and behavioral change efforts. Revamping the Primary Health Care systems is critical for nutrition improvement especially in areas with high nutrition burden.

During the last few years, the government of Nigeria has made significant progress in the development of sectoral policies among which are the National Health Policy, the National Policy on Food and Nutrition, the associated Plan of Action, and the recent Integrated Newborn and Child Health Strategy. Government, however, needs to move into active and effective implementation. The significant and negative effects of the absence or poor functioning of these basic services on health and nutrition of mothers, as shown by this study's results, reflect the huge challenges facing the implementation of the National Health Policy, National Policies on Food and Nutrition, the associated Plans of action, and the primary healthcare system itself.

Typologies of Vulnerability to Child and Maternal Malnutrition in Nigeria

Vulnerability, generally refers to a state of being or likely to be in a risky situation, and nutritionally it refers to the presence of factors that place a child or person at risk of becoming malnourished or food insecure, whether due to loss of access to food, proper nutritional care, or an inability to physiologically utilize available food because of infection or other disease. Based on the OLS regression results, with no further advanced procedures applied, the range of economic, sociodemographic, nutritional, and public health determinants of maternal and child malnutrition are organized into a frame (Table 24) to reflect in the simplest form, the typologies of vulnerability of children and mothers to malnutrition. The significant determinants of child and maternal malnutrition influenced the considerations and notions of vulnerability. Thus, Table 24 also summarizes the key findings of the study.

Conclusions and Policy Implications

Conclusions

Significant variations exist in the level of child and maternal malnutrition across rural urban settings, geopolitical regions and abroad agroecological bands in Nigeria. Malnutrition rates are higher among rural households who depend more on agriculture than on other sectors for their livelihoods. A range of socioeconomic, demographic, and public health related factors work together to influence maternal and child nutrition outcomes among rural and urban dwellers across the geopolitical regions and agroecological zones in Nigeria.

The results indicate that generally, across rural and urban areas, household economic status is significantly and positively associated with child nutrition, though with very limited effect. Its impact is found in rural North East and South region, and in urban areas of the North East, North West and in the South region. Across the agroecological zones, it is found to have similar level of effects in sudano-sahelian savannah and the humid forest zone. On maternal nutrition, it has similar effects generally in the rural and urban areas, and specifically in rural North Central and South regions, and in all the urban regions excepting the North East, as well as across all the rural and urban areas of the agroecological zones. Although relatively weak in effect, the consistency and wide reach of the effect of household economic status indicates its relative importance to child and maternal nutrition. Covering both rural and urban areas may maximize the effect of programmes designed to improve household economic status to enhance both child and maternal nutrition.

Although the primary engagement of household heads in agriculture is related to their household socioeconomic status, the negative and significant effect of this work status on child and maternal nutrition is established, controlling for the effect of household economic status. The results amply indicate that the negative effect of household heads being primarily engaged with agriculture on child growth is particularly a rural phenomenon, in North Central and South regions and the humid forest zone.

Another variable that relates to wealth or income, mother working to generate income has a positive effect on height-for-age independent of household wealth status generally

in rural areas, and specifically in rural North Central and North West. It also has significant and positive effect in rural Sudano-Sahelian and Guinea savannahs and in urban humid forest zone and on the mother, the effect of maternal work on her nutritional well-being is high, positive and significant in rural areas generally, and specifically, in rural North East and the South regions, and in rural Guinea savannah with no significant effects in the urban areas of the regions and agroecological zones. This study indicates that allowing mothers to work to earn their own income would substantially contribute to the reduction of child malnutrition in the regions and zones that have the highest burden of malnutrition in the country (especially North West and Sudano Sahelian savannah).

Maternal education appears to be the determinant with the highest potential of reducing child malnutrition especially in urban areas of North Central, North West and North East. Going beyond primary to secondary education is associated, however, with substantial increase in height-for-age Z-scores in rural Guinea savannah, and in urban Sudano Sahelian savannah. While maternal education affects child malnutrition more in the urban Northern regions, its effect on maternal nutrition is associated more with the rural northern regions and zones especially with rural North East and Northwest.

Other significant maternal and child related characteristics and public health factors include age of mother, age of child, being a female child and immunization (BCG) vaccinations, and considering distance as a constraint accessing or using basic health services. The significant and negative effect of age of child on child nutritional status is almost universal cutting across almost all rural and urban regions and agroecological zones as nutritional status is found to deteriorate with age at a monthly height-for-age Z-score rate of 0.06 in North Central, 0.10 in North East, 0.09 in the North West, and 0.05 in the South region. The results confirm that that stunting rate is lowest among children under 6 months, increases significantly after 6 months and peaks after the first year into the second year. For children 6-36 months, our results indicate that dietary diversity and increased daily meal frequencies hold a strong potential for improved child nutrition.

Despite wide and significant variations in attendance of antenatal visits across the regions and zones, antenatal visits appear limited in effect on child growth. Quality of service obtained may matter more than mere attendance. Distance related constraints to accessing healthcare are likely to influence maternal nutrition in the rural areas than in the urban.

Policy Implications

The independent effects of household economic status, household head being primarily engaged with agriculture and maternal work to earn income combine to indicate that efforts to improve livelihoods are central to improving nutritional status especially in rural areas. Effectively implementing the income generating components of various policies such as the National Agriculture Policy, National Economic Empowerment for Development II, Rural Development Strategies, and National Plan of Action on Nutrition, especially in rural areas, could substantially influence nutrition outcomes. While special attention is needed in the northern geopolitical regions and in the Sudano-Sahelian and Guinea savannah zones, addressing urban nutrition challenges through efforts that improve livelihoods across all regions and zones is also important. These factors are linked with poverty, low income, and assets base and are characterized by poor environmental health situations in terms of access to water and sanitation which significantly influence nutrition outcomes.

High malnutrition rates among agriculture dependent households reflect challenges facing rural farmers in Nigeria that include: low incomes constraints to optimum access to inputs, market uncertainties that act as disincentives to increased investment in agriculture, poor rural infrastructure and poor agricultural policy implementation. The 2001 New National Agriculture Policy (NAP) has creating gainful employment as one of its objectives and recognized the need to improve facilities and incentives such as rural infrastructure and primary health care, amongst others, in order to encourage agricultural and rural development (FMANR & RD 2002; Fan, Omilola, Rhoe, and Salau 2008). A major strategy of the new agriculture policy is to articulate and implement integrated rural development programs to raise the quality of life of the rural people. Also, the 2001 rural development sector strategy identified physical and social infrastructural development as key to improving the lives of the rural farming populace.

Women's education at various levels is important to improve both child and maternal nutrition. While strengthening efforts to increase overall enrollments and quality of education nationally, the range of barriers that have substantially limited generations of women and girls especially in North East and West and in the Sudano Sahelian and Guinea savannahs need be identified and frontally addressed as a matter of highest development priority. Considerations for improving quality of education, mass literacy programs, and effective communication of relevant nutrition and health messages are indicated. Policy and program efforts that promote women having basic education and exceeding primary education level are important to reduce undernutrition. Mass literacy programs integrated in behavioral change and specific health and nutrition communications must be strengthened for accelerated building of women's capacities for knowledgeable care.

There are regional disparities between the southern and northern zones with regard to enrollments and the national policy on education recognizes and seeks to address issues of imbalance in the provision of education in different parts of the country. The enrollments were as high as 95 percent in Southern zones and as low as 19.91 percent in the northern zones (Moja 2000; NPC/ORC Macro 2004). Gender disparities exist and are also similar to the general patterns for enrollment in different regions. In the context of multi-sectoral programming, the National Plan of Action for nutrition supports the strategies of promoting nutrition education and training of care givers, including men at household levels, and educating the girl child and women as they form the bulk of the caregivers at the household level.

The government has established the National Commission on Mass Literacy and Adult and Nonformal Education to address the educational needs of many adults who may no longer get back to school and efforts were also made to incorporate health and nutrition programs into these mass literacy programs to improve access to basic knowledge relevant for improved nutrition. While there is need for more research on problems pertaining to specific zone areas, such as attendance fluctuations due to seasonal variations, and for suitable strategies to overcome them, addressing the cultural attitudes and practices such as early marriage for girls amongst others in the northern zones through integrated efforts of several agencies such as UNICEF, the Ministry of Women Affairs, and other stakeholders hold significant potential for positive change.

Poor public health conditions and services significantly influence welfare and nutrition of resource limited rural and agriculture-dependent populations. The National Primary Health Care Development Agency, The Federal Ministry of Health, and supporting

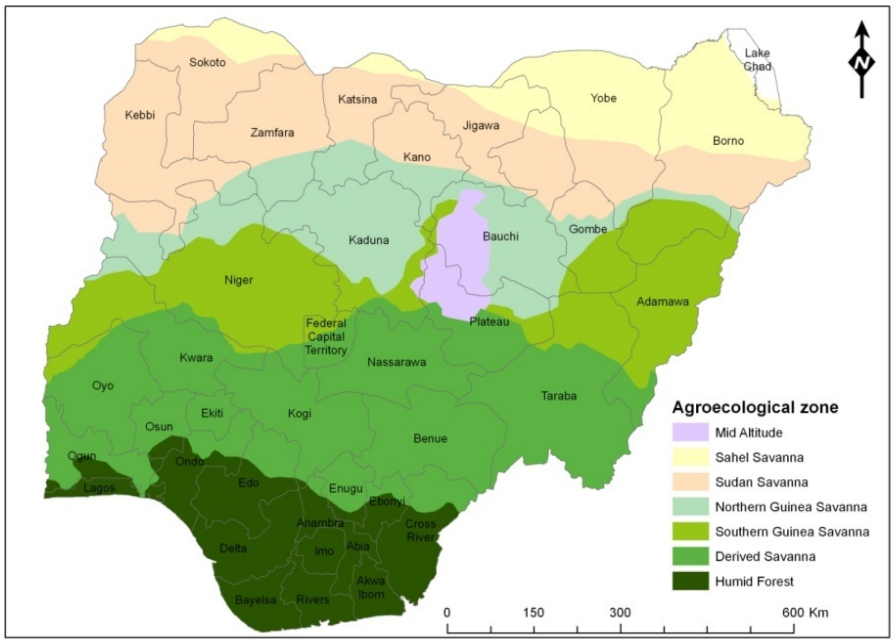
agencies and partners must address the basic challenges to primary health care in Nigeria. An effective primary health care system will substantially increase use of health services such as antenatal care, modern family planning for improved child spacing, routine immunization, micronutrient supplementation, safe maternity service, and promotion of optimum infant feeding practices all of which were found to be significant in reducing malnutrition.

Current efforts to effectively implement the Integrated Maternal, Newborn, and Child Health Strategy must be sustained to achieve the objectives of the strategy. Given the demonstrated importance of infant and young child feeding to child growth, the developed national strategy for infant and young child feeding in Nigeria should be operationalized and applied to all regions and zones. While strengthening the primary healthcare system, it is important that well targeted community based and integrated agriculture, nutrition, and health programs are implemented for timely and sustainable reduction of maternal and child malnutrition.

The range of determinants identified can all be addressed under efforts to meet the MDGs. Fully incorporating and sustaining focus on these determinants that represent basic elements of socioeconomic development will result in substantial reduction in child and maternal mortality and undernutrition in the process of meeting the MDGs.

For future research, it may be important to evaluate trends and rate of change in child growth from 1990 to 2008 as well as to understand the spatial and temporal changes in determinants of child growth within this period. It is also important to better understand how our policymaking processes and implementation strategies could best facilitate effective policy and program responses to region specific peculiarities and priorities that are critical for improved maternal and child nutrition outcomes in Nigeria.

Figure 1. Major agroecological zones in Nigeria [1]



[1] The seven agroecological zones were reclassified to form four broad agroecological bands for purposes of analysis: 1. Sudano-Sahelian zone (Borno, Yobe, Jigawa, Kano, Katsina, Zamfara, Sokoto, and Kebbi States); 2.Guinea savannah (Kaduna, Bauchi, Gombe, Adamawa, Niger, and Plateau states); 3. Derived savannah (Oyo, Kwara, Osun, Ogun, Ekiti, Kogi, Nasarawa, Benue, Taraba, FCT, and Enugu States); and 4. Lagos, Ondo, Edo, Delta, Bayelsa, Rivers, Imo, Anambra, Abia, Akwa-Ibom, Cross River, and Ebonyi States). The 2001-2003 National Food Consumption Survey divided the country into three broad agroecological zones: dry savannah, moist savannah, and the humid forest zones. The dry savannah was a very broad classification that covered the Sahel, Sudan, Northern Guinea and part of the Southern Guinea savannah; the moist savannah covered part of the southern savannah and the derived savannah while the humid forest remains the same. In this study, four divisions were used to capture the more, though broad, substantial differences across the agroecological bands. Using the seven agroecological zones would pose substantial challenges related to sample size as the study was not originally designed within the agroecological zones' framework. In classifying states into four zones based on essential similarities that influenced the delineation of agro zones, states were considered on the basis of the agroecological zone that predominantly covers the state, as some states may lie within two or more agro ecological zones. Thus, though a useful classification, it is limited by the fact that while most of the states were effectively captured in this classification, a few may not have been completely covered. The portion of the states not captured in current classifications may explain differences when estimates from this classification are compared with estimates from a survey that is designed within the framework of the seven agroecological zones. No such study, however, has been conducted to the best of our knowledge.

Figure 2. Mean height-for-age Z-scores by age of children 0-36 months

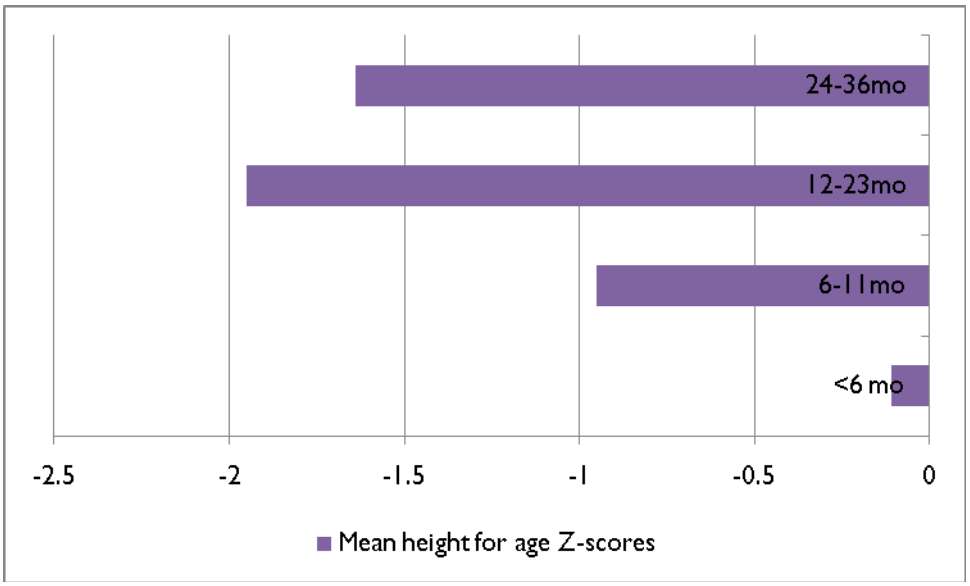


Table 1. Specified variables and their types

Variables	Type
Dependent variables	
Height-for-age Z-scores*	Continuous
Whether child was stunted	Dichotomous
Body Mass Index (dependent variable for the women model)	Continuous
Independent variables (Socioeconomic)	
Household economic status	
Household wealth score*	Continuous
Whether household is at lowest, poorer, middle, richer, or richest level	Dichotomous
Occupation	
Whether household head is primarily involved with agriculture*	Dichotomous
Whether woman works for income*	Dichotomous
Whether woman decides on use of income alone*	Dichotomous
Use of safe water and sanitary toilet	
Whether piped and protected well water is used (as opposed to surface and unprotected well water)	Dichotomous
Use of flush toilets	Dichotomous
Use of pit latrines	Dichotomous
No latrine	Dichotomous
Women's education and literacy	
Whether woman has no education*	Dichotomous
Whether woman has primary education*	Dichotomous
Whether woman has secondary or higher education*	Dichotomous
Whether woman can read (literacy)*	Dichotomous
Demographics	
Sex of Household head*	Dichotomous
Age of Household head*	Continuous
Age of woman*	Continuous
Age of woman at first birth*	Continuous
Whether woman is married*	Dichotomous
Household size*	Continuous
Household size sq*	Continuous
Percent of children under five years (% of children under five of household size)*	Continuous
Age of child in months*	Continuous
Whether child is female*	Dichotomous
Location variables	
Whether household lives in a rural area*	Dichotomous
Whether household lives in urban areas*	Dichotomous
Regions*	
North Central	Dichotomous
North East	Dichotomous
North West	Dichotomous
South East	Dichotomous
South	Dichotomous
South West	Dichotomous
Agroecological zones*	
Sudano Sahelian savannah	Dichotomous
Guinea savannah	Dichotomous
Derived savannah	Dichotomous
Humid forest	Dichotomous

Table 1. Specified variables and their types (continued)

Specification	Type
Proximate variables	
Use and availability of health services	
Number of antenatal visits	Continuous
Whether woman had any antenatal care	Dichotomous
Whether woman had at least four visits	Dichotomous
Whether woman gave birth in a medical facility	Dichotomous
Whether a child has ever been vaccinated	Dichotomous
Whether child had BCG (a very basic vaccination)	Dichotomous
Maternal nutritional status	
Woman's Body Mass Index (BMI)	Continuous
Whether woman is chronically energy deficient (undernourished, BMI less than18.5)	Dichotomous
Infant feeding practices	
Whether mother of child 0-24 months initiated breast feeding within first hour of birth	Dichotomous
Whether children 6-11, 12-23, and 24-36 months received a minimum acceptable diet (a function of minimum frequency and diversity) previous day to the survey	Dichotomous
Whether children 6-11, 12-23, and 24-36 months were fed from at least 4 food groups previous day to the survey	Dichotomous
Whether children 6-11, 12-23, and 24-36 months were fed the minimum number of times for their ages previous day to the survey	Dichotomous
Diversity of complementary food fed child–dietary diversity score	Continuous
Other variables used only in the woman model other than child related variables	
Age at first birth*	Continuous
Parity*	Continuous
Whether distance to health facility is a problem*	Dichotomous

*****Only variables marked with asterisks were covered in the regression model while all variables were used in descriptive analysis and comparison of level of determinants across locations and zones.

Table 2. Relative incidence of poverty by occupation of household heads[2]

	Poverty Head Count				
Occupational Categories	**1980**	**1985**	**1992**	**1996**	**2004**
Professional/Technical	17.3	35.6	35.7	51.8	34.2
Administration	45.0	25.3	22.3	33.5	45.3
Clerical and related	10.0	29.1	34.4	60.1	39.2
Sales workers	15.0	36.6	33.5	56.7	44.2
Service industry	21.3	38.0	38.2	71.4	43.0
Agricultural and forestry	31.5	53.5	47.9	71.0	67.0
Production and transport	23.2	46.6	40.8	65.8	42.5
Manufacturing and processing	12.4	31.7	33.2	49.4	44.2
Others	1.5	36.8	42.8	61.2	49.1
Students and apprentices	15.6	40.5	41.8	52.4	41.6

[2] National Bureau of Statistics 2005. Poverty Profile of Nigeria.

Table 3. Tests of endogeneity of potential endogenous explanatory variables and relevance and exogeneity of instrument variables (IVs)

Potentially endogenous variables and instruments	Test of endogeneity (DWH test)	F-test of relevance	J Hansen test of over identification	Status after test
BMI IV : Age of woman F statistics:	8.40 (p=0.004)	17.25 (p=0.000)	Not applicable for one instrument variable (na)	BMI endogenous
Antenatal care (Number of visits) IV set: Women education dummies F statistics:	1.13 (p=0.29)	6.30 (p=0.002)	0.68(p=0.41)	Antenatal care not endogenous
Distance to health facility is a problem F statistics:	0.12 (p=0.73)	14.66 (p=0.0001)	na	
Use of electricity (as proxy for income) F statistics:	0.84 (p=0.36)	0.00 (p=0.99)	na	
ALL (ANC instruments) F statistics:	0.96 (p=0.33)	6.66 (p=0.000)	2.62 (p=0.45)	
Duration of breastfeeding IV: Use of contraceptives F statistics:	2.60 (0.11)	2.72 (0.10)	na	Endogenous, test not relevant
IYCF (child having minimum acceptable diet in a day) IV set: V161 F statistics:	2.46 (p=0.12)	0.17 (p=0.68)	na	Endogenous
Use of electricity F statistics:	7.61 (p=0.006)	0.44(p=0.51)	na	
Women reading literacy F statistics:	3.71 (p=0.05)	3.32(p=0.07)	na	

Table 3. Tests of endogeneity of potential endogenous explanatory variables and relevance and exogeneity of instrument variables (IVs) (continued)

Potentially endogenous variables and instruments	Test of endogeneity[3] (DWH test)	F-test of Relevance	J Hansen test of overidentification identification	Status after test
IYCF....IV sets Agrichh F statistics: All (IYCF instruments) F statistics:	6.10 (p=0.014) 3.62 (p=0.06)	0.06 (p=0.81) 0.13(p=0.97)	na 0.13 (p=0.987)	Endogenous
BCG (receiving bcg) vaccines IV set: Distance alone F statistics: Distance and women education dummies F statistics:	4.32 (p=0.04) 2.56 (p=0.11)	7.66 (p=0.01) 14.7 (p=0.00)	0.04 (p=0.85) 3.11 (p=0.21)	Not endogenous

Table 4. Prevalence of stunting and chronic energy deficiency

	Stunting in children 0-36 months (percents)		Chronic energy deficiency in mothers (percents)
Variables	**<-2.0 SD**	**<-3.0SD**	**BMI <18.5**
Place of Residence			
Rural	37.1	20.3	16.5
Urban	26.4	12.4	12.7
Region			
North Central	26.0	10.2	7.1
North East	35.5	17.2	22.1
North West	51.4	33.3	20.0
South East	18.5	8.5	9.4
South South	17.2	6.1	11.5
South West	22.2	8.5	16.3
Agroecological zones			
Sudano Sahelian savannah	47.8	30.3	22.7
Guinea savannah	40.0	18.9	16.8
Derived savannah	22.7	9.4	11.2
Humid forest	18.4	7.5	11.4

[3] If Wu-Hausman F test is significant, then null hypothesis is rejected, meaning that OLS is not consistent. Where Wu-Hausman F test is not significant, null hypothesis is accepted, meaning that OLS is consistent.

Table 5. Mean height-for-age Z-scores

	All		Rural		Urban	
Variables	**Mean (std. err.)**	**Obs**	**Mean (std.err.)**	**Obs**	**Mean (std.err.)**	**Obs**
Region						
North Central	-1.081 (0.072)	521	-1.183 (0.086)	335	-0.897 (0.126)	186
North East	-1.442 (0.066)	676	0.086 (0.086)	417	-1.323 (0.102)	259
North West	-2.080 (0.070)	757	-2.251(0.083)	547	-1.632 (0.121)	210
South East	-0.753 (0.107)	260	-0.733(0.139)	139	-0.777 (0.167)	121
South South	-0.650 (0.100)	279	-0.747(0.126)	185	-0.459 (0.161)	94
South West	-0.883 (0.090)	329	-0.987(0.146)	131	-0.815 (0.115)	198
Agroecological zones						
Sudano Sahelian savannah	-1.977 (0.067)	768	-2.205(0.0890	483	-1.590 (0.094)	285
Guinea savannah	-1.557 (0.062)	785	-1.656(0.072)	563	-1.308 (0.118)	222
Derived savannah	- 0.921 (0.066)	638	-0.976(0.085)	380	-0.841 (0.107)	258
Humid forest	-0.716 (0.068)	631	-0.797(0.094)	328	-0.628 (0.097)	303
Household economic status						
Poorest	-1.589(0.074)	589	-1.604(0.076)	542	-1.414 (0.285)	47
Poorer	-1.706(0.0780	559	-1.727(1.869)	460	-1.609 (0.173)	99
Middle	-1.570(0.080)	564	-1.671(1.905)	389	-1.344 (0.140)	175
Richer	-1.117(0.072)	574	-1.094(1.784)	238	-1.132 (0.093)	336
Richest	-0.680(0.070)	536	-0.438(1.628)	125	-0.753 (0.079)	411
Maternal education						
No education	-1.753 (0.051)	1290	-1.847 (0.060)	961	-1.481 (0.060)	329
Primary	-1.232 (0.068)	708	-1.308 (0.089)	439	-1.108 (0.089)	269
Secondary	-0.785 (0.056)	824	-0.079 (0.084)	321	-0.793 (0.084)	470
Body Mass Index of Mother						90
Underweight	-1.823 (0.104)	318	-1.980 (0.125)	228	-1.425 (0.178)	550
Normal	-1.273 (0.045)	1624	-1.386 (0.056)	1074	-1.052 (0.743)	258
Overweight	-0.791 (0.079)	453	-0.908 (0.122)	195	-0.703 (0.104)	
Female child						
No	-1.425(0.049)	1407	-1.598(0.0630	868	-1.14(0.078)	539
Yes	-1.255(0.0472)	1415	-1.402(0.0620)	886	-1.01(0.072)	529
Whether woman has at least four antenatal care visits						
No	-1.226(0.091)	369	-1.314(0.107)	255	-1.03(0.17)	114
Yes	-1.087(0.048)	1295	-1.199(0.072)	632	-0.98(0.061)	663
Whether female-headed household						
No	-1.379(0.036)	2581	-1.543(0.046)	1627	-1.10(0.06)	954
Yes	-0.918(0.121)	241	-0.938(0.1620)	127	-0.90(0.18)	114

Table 5. Mean comparisons of height-for-age Z-scores (continued)

Variables	All		Rural		Urban	
	Mean (std. err.)	Obs	Mean (std.err.)	Obs	Mean (std.err.)	Obs
Whether household head is primarily involved with agriculture						
No	-1.196(0.0412)	1876	-1.33(0.061)	938	-1.06(0.06)	938
Yes	-1.624(0.0601)	946	-1.69(0.064)	816	-1.18(0.17)	130
Whether piped and protected water is used						
No	-1.553(0.0451)	1632	-1.618(0.51)	1278	-1.32(0.10)	354
Yes	-1.0466(0.0512)	1190	-1.179(0.087)	476	-0.96(0.06)	714
Whether woman can read (literacy)						
No	-1.636(0.0458)	1653	-1.75(0.054)	1200	-1.34(0.083)	453
Yes	-9.20(0.0486)	1169	-0.96(0.070	554	-0.89(0.067)	615
Whether woman is married						
No	-0.933(0.149)	151	-0.83(0.208	85	-1.063(0.21	66
Yes	-1.363(0.035)	2671	-1.53(0.045	1669	-1.080(0.06	1002
Whether mother decides on use of income alone						
No	-1.27(0.044)	1712	-1.39(0.055	1106	-1.07(0.07	606
Yes	-1.442(0.0551)	1110	-1.69(0.074	648	-1.09(0.08	462
Whether woman works for income						
No	-1.467(0.060)	1004	-1.62(0.077)	628	-1.22(0.10)	376
Yes	-1.27(0.0415)	1806	-1.44(0.054)	1119	-0.10(0.06)	687
No Latrine						
No	-1.318(0.040)	2085	-1.52(0.056)	1137	-1.078(0.056)	948
Yes	-1.400(0.066)	737	-1.50(0.072)	617	-1.077(0.157)	120
Use of flush toilets						
No	-1.444(0.036)	2490	-1.54(0.05)	1668	-1.256(0.061)	822
Yes	-0.556(0.090)	332	-0.77(0.20)	86	-0.483(0.099)	246
Use of pit latrines						
No	-1.153(0.054)	1117	-1.39(0.067)	734	-0.708(0.085)	383
Yes	-1.462(0.044)	1705	-1.58(0.058)	1020	-1.28(0.066)	685
Whether child has had BCG						
No	-1.640(0.051)	1405	-1.72(0.059)	1052	-1.38(0.096)	353
Yes	-1.042(0.045)	1413	-1.16(0.063)	698	-0.93(0.063)	715
Whether woman has any antenatal care during pregnancy						
No	-1.658(0.055)	1158	-1.77(0.064)	867	-1.32(0.105)	291
Yes	-1.118(0.043)	1664	-1.23(0.060)	887	-0.99(0.061)	777
Whether mother of child 0-24 months initiated breastfeeding within first hour of birth						
No	-1.45(0.0419)	1894	-1.64(0.053)	1200	-1.12(0.067)	694
Yes	-.134(0.0589)	909	-1.20(0.080)	544	-1.03(0.086)	365
Whether delivered child in health facility						
No	-1.655(0.045)	1690	-1.75(0.053)	1228	-1.41(0.079)	462
Yes	-0.087(0.05)	1129	-0.92(0.073)	525	-0.823(0.07)	604

Whether child 6-11 months received a minimum acceptable diet						
No	-1.04 (0.08)	442	-1.09 (0.09)	298	-0.95 (0.13)	132
Yes	-0.94 (0.18)	101	-1.20 (0.25)	58	-0.59 (0.20)	55
Whether child 12-23 months received a minimum acceptable diet						
No	-2.24 (0.08)	435	-2.40 (0.09)	310	-1.93 (0.20)	88
Yes	-1.99 (0.12)	162	-2.1 (0.17)	93	-1.84 (0.13)	106
Whether child 24-36 months received a minimum acceptable diet (nbf)						
No	-1.87 (0.08)	506	-2.10 (0.10)	310	-1.57 (0.12)	196
Yes	-1.15 (0.15)	126	-1.48 (0.22)	68	-0.76 (0.18)	58
Whether child 6-11 months were fed from at least 4 food groups a day prior to survey						
No	-1.03 (0.08)	412	-1.06 (0.10)	280	-0.95 (0.13)	132
Yes	-0.99 (0.15)	131	-1.29 (0.21)	76	-0.59 (0.21)	55
Whether child 12-23 months were fed from at least 4 food groups a day prior to survey						
No	-2.30(0.10)	321	-2.40 (0.11)	233	-1.93 (0.20)	88
Yes	-2.10(0.09)	276	-2.20 (0.12)	170	-1.84 (0.13)	106
Whether child 24-36 months were fed from at least 4 food groups a day prior to survey (nbf)						
No	-1.85 (0.11)	263	-2.10 (0.13)	169	-1.40 (0.19)	94
Yes	-1.65 (0.09)	369	-1.86 (0.13)	209	-1.37 (0.12)	160
Whether child 6-11 were fed at least twice a day prior to the survey						
No	-1.28 (0.10)	246	-1.40 (0,12)	174	-1.01 (0.17)	74
Yes	-0.80 (0.09)	297	-0.84 (0.12)	184	-0.74 (0.15)	113
Whether child 12-23 months were fed at least 3 times a day prior to survey						
No	-2.39 (0.09)	299	-2.50 (0.11)	215	-2.10 (0.18)	84
Yes	-1.96 (0.09)	298	-2.10 (0.12)	188	-1.72 (0.14)	110
Whether child 24-36 months were fed at least 4 times a day prior to survey (nbf)						
No	-1.86 (0.08)	434	-2.10 (0.11)	273	-1.55 (0.13)	161
Yes	-1.43 (0.12)	198	-1.73 (0.17)	105	-1.11 (0.17)	93

Table 6. Mean Body Mass Index (BMI) of determinant categories

	All		Rural		Urban	
Variables	**Mean (std. err.)**	**Obs**	**Mean (std.err.)**	**Obs**	**Mean (std.err.)**	**Obs**
Region						
North Central	23.00(0.124)	1106	22.53(0.14)	656	23.69(0.22)	450
North East	21.54(0.118)	1157	21.09(0.14)	708	22.24(0.21)	449
North West	21.44(0.098)	1458	20.99(0.104)	1023	22.50(0.21)	435
South East	22.77(0.14)	998	22.52(0.16)	588	23.12(0.23)	410
South South	23.19(0.17)	826	22.61(0.202)	516	24.20(0.30)	310
South West	22.23(0.14)	1061	21.42(0.19)	414	22.74(0.19)	647
Agroecological zone						
Sudano Sahelian savannah	21.26(0.100)	1432	20.72(0.11)	867	22.07(0.18)	565
Guinea savannah	2199(0.105)	1458	21.48(0.11)	1039	23.30(0.23)	419
Derived savannah	22.43(0.101)	1689	22.13(0.13)	934	22.80(0.16)	755
Humid forest	23.03(0.105)	2027	22.54(0.13)	1065	23.58(0.17)	962
Household economic status						
Poorest	21.16(0.10	1257	21.10(0.11)	1141	21.16(0.10)	116
Poorer	21.40(0.101	1187	21.37(0.11)	980	21.40(0.10)	207
Middle	22.02(0.11	1287	21.91(0.13)	901	22.02(0.12)	386
Richer	22.38(0.11	1346	22.21(0.16)	539	22.40(0.11)	807
Richest	23.95(0.13	1529	23.96(0.25)	344	24.00(0.13)	1185
Maternal education						
No education	21.64(0.079)	2493	21.22(0.09)	1817	22.76(0.17)	676
Whether woman has primary education	22.36(0.11)	1450	21.92(0.12)	897	23.08(0.21)	553
Whether woman has secondary education	22.80(0.09)	2663	22.45(0.12)	1191	23.10(0.13)	472
Female-headed household						
No	22.18(0.057	5429	21.69(0.07)	3321	22.93(0.10)	2108
Yes	22.67(0.14	1177	22.13(0.18)	584	23.21(0.21)	593
Whether household head is primarily involved with agric						
No	22.44(0.063)	4923	21.86(0.08)	2477	23.02(0.10)	2446
Yes	21.77(0.091)	1683	21.58(0.10)	1428	22.81(0.25)	255
Whether piped and protected water is used						
No	21.74(0.066)	3507	21.57(0.07)	2660	22.30(0.14)	847
Yes	22.85(0.083)	3099	22.16(0.11)	1245	23.32(0.12)	1854
Whether woman can read (literacy)						
No	21.71(0.070)	3156	21.31(0.08)	2259	22.72(0.15)	897
Yes	22.77(0.077)	3450	22.38(0.102)	1646	23.13(0.11)	1804

Table 6. Mean Body Mass Index (BMI) of determinant categories (continued)

	All		Rural		Urban	
Variable	**Mean (std. err.)**	**Obs**	**Mean std.err.)**	**Obs**	**Mean (std.err.)**	**Obs**
Whether woman decides alone on earned income						
No	21.84(0.06)	4357	21.53(0.07)	2705	22.40(0.11)	1652
Yes	23.08(0.101)	2249	22.28(0.12)	1200	24.00(0.16)	1049
Whether woman works to for income						
No	21.34(0.07)	2939	21.04(0.083)	1769	21.80(0.12)	1170
Yes	23.00(0.075)	3652	22.36(0.09)	2128	24.00(0.13)	1524
Location						
Urban	22.99(0.10)	2701				
Rural	21.76(0.062)	3905	-	-	-	-
No Latrine						
No	22.51(0.063)	4901	21.95(0.08)	2504	23.08(0.10)	2397
Yes	21.57(0.091)	1705	21.41(0.10)	1401	22.31(0.21)	304
Use of flush toilet						
No	21.97(0.054)	5610	21.62(0.062)	3654	22.61(0.10)	1956
Yes	23.96(0.17)	996	23.76(0.062)	251	24.02(0.20)	745
Use of pit latrines						
No	22.41(0.084)	2854	21.77(0.10	1756	23.44(0.15)	1098
Yes	22.15(0.068)	3752	21.75(0.08	2149	22.70(0.12)	1603
Whether distance is constraint to healthcare						
No	22.67(0.074)	3700	22.14(0.10)	1761	23.14(0.11)	1939
Yes	21.75(0.073)	2887	21.44(0.08)	2129	22.63(0.16)	758

Table 7. Chow's F test of structural difference (parameter stability) across the regions, agroecological zones and rural urban locations

Variable	Child model (Z-score Height-for-age=dependent variable)	Women model (Body Mass Index =dependent variable)
Regions		
N	2403	4297
F statistic	22.41	1462.2
P value	0.000	0.000
R squared	0.55	0.97
Agroecological zones		
N	2403	4297
F statistic	32.33	1798.0
P value	0.000	0.000
R squared	0.54	0.97
Type of place of residence (locations)		
N	2403	4297
F statistic	59.7	3565.0
P value	0.000	0.000
R squared	0.52	0.97

Table 8. Comparison of determinants of child malnutrition across rural areas of the geopolitical regions

Socioeconomic variables	North Central	North East	North West	South East	South South	South West	P values
House economic status (percent)							
Poorest	30.4	49.6	25.4	11.2	25.8	38.9	0.0001
Poorer	23.4	26.2	34.3	26.1	16.0	18.1	0.0002
Middle	24.2	14.2	27.9	21.1	21.7	12.5	0.0010
Richer	15.5	8.0	11.1	24.2	18.9	15.3	0.0180
Richest	6.5	2.1	1.3	17.4	17.5	15.3	0.0001
Sex of household head							
Percent of female-headed household	9.0	1.3	4.0	18.6	20.7	9.0	0.0001
Percent of household head involved in agriculture	50.8	50.8	52.6	26.1	21.7	59.7	0.0001
Use of safe water							
Percent of household using safe water	24.5	11.5	23.4	65.2	40.6	25.7	0.0001
Latrine use (percent)							
None	51.6	26.6	23.8	28.0	42.9	67.4	0.0001
Pit latrine	3.2	2.5	1.3	13.7	12.4	6.9	0.0001
Flush toilet	43.2	69.9	73.9	55.9	40.6	21.5	0.0001
Percent of women who work for income	76.8	51.3	53.6	60.9	72.2	93.1	0.0001
Maternal education (percent)							
None	39.7	77.2	80.6	10.6	9.2	34.0	0.0001
Primary	41.0	14.9	12.1	38.5	35.0	38.2	0.0001
Secondary	19.3	8.0	7.4	50.9	55.8	27.8	0.0001
Percent of women who can read	29.6	15.3	13.6	79.5	69.1	49.3	0.0001
Mean age of women	28.0	27.7	26.8	30.3	28.2	29.8	0.0000
Mean age of household head	41.3	41.3	39.0	43.9	44.5	41.5	0.0000
Mean of household size	7.9	7.8	7.1	6.3	7.3	5.6	0.0000
Mean percent of children under 5 years	32.5	32.7	34.4	33.4	29.0	34.2	0.0000
Percent of married women	94.6	95.8	98.6	92.6	83.4	98.6	0.0297
Percent women decide alone on income	65.0	71.0	82.0	70.0	53.0	70.0	0.0001
Mean age of children in months	17.0	16.4	15.4	17.1	17.6	15.2	0.0325
Percent of female children	51.9	48.5	49.7	51.6	50.2	50.7	0.9723
Mean birth order of child	3.9	4.5	4.3	3.7	3.6	3.5	0.0000

Proximal variables	North Central	North East	North West	South East	South South	South West	P value
Mean number of antenatal care visits	3.5	1.8	1.7	7.0	5.0	8.6	0.000
Percent women who had at least one antenatal visit	62.2	38.1	31.6	67.7	66.4	84.0	0.0001
Percent of women who had at least four antenatal visits	70.3	53.9	61.4	84.4	78.5	98.4	0.0001
Percent of women who delivered at health facility	40.0	13.8	6.5	86.3	47.9	66.0	0.0001
Mean Body Mass	22.6	21.1	21.0	23.5	23.6	22.2	0.0000
Percent of women underweight	6.8	25.7	19.9	3.6	6.2	7.5	0.0001
Percent of child ever vaccinate	70.1	50.2	54.3	68.0	71.8	83.8	0.0001
Percent of child sick two weeks prior survey	42.9	61.5	47.1	40.4	41.5	34.0	0.0001
Percent of mothers who initiated breastfeeding within first hour of birth	40.9	26.1	25.1	53.8	39.2	7.8	0.0001
Mean dietary diversity for children: 6-11mo 12-23mo 24-36mo 24-36mo	 2.2 2.5 2.9 3.4	 1.3 3.0 2.8 3.7	 1.9 3.2 3.1 3.6	 2.8 3.6 3.0 3.6	 1.8 3.0 3.4 4.1	 1.8 3.2 3.0 4.0	 0.0004 0.13 0.42 0.20
Percent of children fed at least 2 times/d: 6-11mo Percent fed at least 3 times/d: 12-23mo 24-36mo 24-36 (nbf-4 times/d)	 65.8 55.1 76.0 32.1	 36.2 41.4 74.5 27.7	 41.0 37.6 65.5 21.0	 71.0 68.4 66.7 42.4	 76.3 61.3 76.6 28.6	 50.0 53.1 89.2 56.5	 0.0001 0.01 0.18 0.07
Percent of children fed minimum acceptable diet: 6-11mo 12-23mo 24-36mo 24-36mo (nbf)	 17.8 18.0 30.2 19.2	 11.7 19.8 37.0 16.8	 12.7 22.1 24.0 10.8	 25.8 42.1 35.2 30.3	 18.4 25.8 39.0 21.4	 11.1 40.6 48.6 47.8	 0.84 0.04 0.10 0.08
Percent of children reached with vitamin A supplement	26.6	18.5	9.1	52.8	47.9	75.7	0.0001
Percent of children who had BCG vaccination	54.9	24.9	14.0	73.3	63.1	77.6	0.0001

Table 9. Comparison of determinants of child nutritional status across urban areas of the geopolitical regions

Socioeconomic variables	North Central	North East	North West	South East	South South	South West	P value
Household economic status (percent)							
Poorest	3.5	6.1	2.1	20.0	0.0	0.0	0.0301
Poorer	6.5	16.6	7.4	17.0	5.1	2.4	0.0419
Middle	10.0	28.1	13.7	25.9	13.1	4.7	0.0001
Richer	41.5	37.0	38.6	11.1	29.3	18.4	0.0001
Richest	38.5	12.2	38.3	25.9	52.5	74.5	0.0001
Sex of household head Percent of female-headed household	7.0	6.4	3.5	23.7	17.2	14.2	0.0085
Percent of household head involved in agriculture	11.0	11.2	9.8	31.9	12.1	4.3	0.0011
Use of safe water Percent of household using water	69.0	40.3	71.6	71.9	78.8	80.2	0.0001
Latrine use (percent)							
None	22.0	1.4	3.2	27.4	8.1	10.8	0.0001
Pit latrine	51.0	88.8	81.8	48.9	47.5	47.6	0.0001
Flush toilet	26.0	8.81	14.0	19.3	42.4	40.1	0.0001
Percent of women work for income	59.6	53.9	46.3	79.1	73.7	83.5	0.0001
Maternal education (percent)							
None	33.5	51.9	46.7	22.2	4.0	5.2	0.0001
Primary	24.5	22.0	20.7	37.0	28.3	25.9	0.1257
Secondary	42.0	26.1	32.6	40.7	67.7	68.9	0.0001
Percent of women who can read	49.0	39.3	49.5	63.7	76.8	83.5	0.0001
Mean age of women	28.2	27.8	27.8	30.5	29.5	29.5	0.0001
Mean age of household head	42.8	41.4	40.8	44.6	41.4	41.5	0.0374
Mean household size	7.5	8.7	7.3	6.3	6.2	5.8	0.0000
Mean percent of children under 5 years	31.3	32.1	33.9	28.6	31.0	35.4	0.0000
Percent of married women	91.0	95.9	95.8	90.4	89.9	96.2	0.7781
Percent of women decide alone on income	64.0	80.0	86.0	61.0	54.0	77.0	0.0001
Mean age of children in months	17.5	16.9	18.2	17.6	17.2	16.4	0.5155
Percent of female children	49.0	49.5	52.6	43.7	52.5	50.5	0.7796
Mean birth order of child	3.4	4.4	4.2	4.2	3.7	3.0	0.0000

Table 9. Comparison of determinants of child nutritional status across urban areas of the geopolitical regions (continued)

Proximal variables	North Central	North East	North West	South East	South South	South West	P value
Mean number of antenatal care visits	5.6	4.0	4.8	5.4	8.1	9.3	0.0000
Percent women ho had at least one antenatal visit	71.0	66.4	60.0	78.5	79.8	84.9	0.0001
Percent of women who had at least four antenatal visits	84.5	73.5	84.2	73.6	91.1	97.7	0.0007
Percent of women who delivered at medical facility	63.0	30.5	33.1	67.2	82.8	87.3	0.0001
Mean Body Mass Index	23.9	22.1	23.1	24.3	25.4	24.5	0.0000
Percent of women underweight	7.4	14.0	12.9	6.9	7.0	8.7	0.7485
Percent of children ever vaccinated	78.9	62.1	64.3	79.5	80.0	91.0	0.0001
Percent of children sick two weeks prior to survey	30.0	55.3	50.2	37.0	28.3	17.0	0.0001
Percent of children reached with vitamin A supplements	45.5	27.1	28.2	56.7	54.6	69.8	0.0001
Percent of child who had BCG vaccinations	74.0	46.4	52.3	77.8	78.8	88.7	0.0001
Mean dietary diversity for children:							
6-11 mo	1.9	1.9	2.3	3.4	4.0	2.6	0.004
12-23 mo	2.8	3.5	3.8	2.9	5.6	3.6	0.001
24-36 mo	2.7	3.3	3.5	3.3	4.4	3.5	0.021
24-36 mo (nbf)	3.4	4.4	4.0	3.3	4.8	4.3	0.005
Percent of children fed at least 2 times/d							
6-11 mo	55.0	55.6	60.5	75.0	85.7	51.4	0.39
Percent of children fed at least 3 times/d:							
12-23 mo	63.2	49.3	53.4	61.0	70.0	58.0	0.79
24-36 mo	94.0	63.8	75.5	69.6	91.2	90.5	0.01
24-36 mo (nbf)	49.0	25.0	24.0	39.0	45.8	46.8	0.08
Percent of children fed minimum acceptable diet:							
6-11 mo	17.5	14.8	18.6	37.5	64.3	23.0	0.002
12-23 mo	34.2	30.4	34.2	26.1	70.0	31.6	0.46
24-36 mo	37.3	34.0	42.5	30.4	64.7	52.4	0.05
24-36 mo (nbf)	20.0	21.7	14.1	19.4	41.7	34.0	0.28

Table 10. Comparison of determinants of child nutritional status across rural agroecological zones

Socioeconomic variables	Sudano Sahelian	Guinea savannah	Derived savannah	Humid forest	P value
Household economic status (percent)					
Poorest	29.0	37.4	38.7	18.8	0.0001
Poorer	35.1	25.8	22.6	19.6	0.0001
Middle	20.6	25.0	19.1	21.7	0.3656
Richer	12.9	9.5	12.2	21.4	0.0155
Richest	2.4	2.2	7.4	18.5	0.0001
Sex of household head Percent of female-headed households	4.4	2.2	10.6	17.7	0.0002
Percent of household heads primarily involved in agriculture	43.3	59.0	53.7	25.9	0.0001
Use of safe water Percent of households using water	25.7	16.3	22.4	47.1	0.0001
Latrine use (percent)					
None	24.1	31.9	52.8	36.5	0.0001
Pit latrine	71.7	65.9	41.2	46.6	0.0001
Flush toilet	2.7	1.3	3.5	13.8	0.0001
Percent of women who work for income	53.7	52.2	85.8	67.6	0.0001
Percent of women who decide alone on income	81.0	77.0	63.0	59.0	0.0016
Maternal education (percent)					
No education	82.9	67.7	42.4	9.5	0.0001
Primary	10.3	21.6	37.1	36.5	0.0001
Secondary	6.8	10.8	20.5	54.0	0.0001
Percent of women who can read	11.0	21.4	33.9	73.0	0.0001
Mean age of women	27.0	27.8	28.1	29.0	0.0001
Mean age of household head	39.5	40.0	42.2	44.1	0.0000
Mean household size	70.6	77.0	73.6	67.8	0.0004
Mean percent of children under 5 years	34.4	33.4	31.6	31.7	0.0005
Percent of married women	98.1	97.3	94.2	87.8	0.0336
Mean age of children in months	15.7	16.3	16.3	17.2	0.1630
Percent of female children	48.3	52.1	49.5	50.3	0.6882

Table 10. Comparison of determinants of child nutritional status across rural agroecological zones (continued)

Proximal variables	Sudano Sahelian	Guinea savannah	Derived savannah	Humid forest	P value
Mean number of antenatal care visits	1.4	2.4	4.4	5.9	0.000
Percent women who had at least one antenatal visit	25.2	49.4	63.8	68.8	0.0001
Percent of women who had at least four antenatal visits	59.8	60.6	78.0	84.6	0.0001
Percent of women who delivered at health facility	6.8	17.3	48.2	62.4	0.0001
Mean birth order	4.4	4.3	3.9	3.6	0.0000
Mean Body Mass Index	21.0	21.4	22.3	23.5	0.0000
Percent of women underweight	22.8	19.5	7.1	5.4	0.0001
Percent of children ever vaccinated	53.2	55.4	70.3	71.2	0.0001
Percent of children sick two weeks prior to survey	50.0	53.6	42.2	40.2	0.0005
Percent of women who initiated breastfeeding within 1 hour of birth	25.8	25.7	36.1	40.8	0.0001
Percent of children fed with vitamin A supplement	10.9	17.7	38.5	53.4	0.0001
Percent of children who had BCG vaccination	16.7	27.8	56.8	68.5	0.0001
Mean dietary diversity for children:					
6-11 mo	1.9	1.5	2.1	2.2	0.04
12-23 mo	3.2	2.7	3.1	3.4	0.04
24-36 mo	3.2	2.7	3.0	3.3	0.04
24-36 mo (nbf)	3.9	3.3	3.6	4.0	0.02
Percent of children:					
6-11 mo fed at least 2 times/d	40.0	39.5	68.5	65.7	0.0001
12-23 mo fed at least 3 times/d	35.8	42.9	56.7	64.0	0.004
24-36 mo fed at least 3 times/d	68.3	69.7	81.1	73.2	0.23
24-36 mo fed at least 4 times/d (nbf)	23.6	26.0	34.8	35.6	0.48
Percent of children fed minimum acceptable diet:					
6-11 mo	12.2	9.3	20.2	22.0	0.34
12-23 mo	23.2	15.3	29.0	38.0	0.06
24-36 mo	26.0	30.0	37.1	41.0	0.09
24-36 mo (nbf)	14.2	12.6	24.7	27.6	0.16

Table 11. Comparison of determinants of child nutritional status across urban agroecological zones

Socioeconomic variables	Sudano Sahelian	Guinea savannah	Derived savannah	Humid forest	P value
Household economic status (percent)					
Poorest	3.4	2.9	8.3	4.6	0.6778
Poorer	12.1	11.6	7.3	6.7	0.5241
Middle	20.7	18.2	13.8	11.9	0.1786
Richer	39.1	34.3	34.8	17.4	0.0158
Richest	24.7	33.1	35.9	59.3	0.0001
Sex of household head Percent of female-headed households	5.5	3.7	14.1	16.2	0.0158
Percent of household heads primarily involved in agriculture	10.2	7.0	16.3	14.1	0.2506
Use of safe water Percent of households using water	58.5	57.9	60.5	84.4	0.0001
Latrine use (percent)					
None	2.4	4.1	29.3	7.6	0.0001
Pit latrine	83.7	77.7	50.4	50.4	0.0001
Flush toilet	12.3	17.8	18.8	39.5	0.0000
Percent of women who work for income	51.7	45.0	75.6	77.3	0.0001
Maternal education (percent)					
No education	53.5	38.0	25.7	9.5	0.0001
Primary	18.1	25.6	30.1	28.1	0.0361
Secondary	28.0	36.4	44.2	62.4	0.0001
Percent of women who can read	40.7	53.3	58.0	76.5	0.0001
Mean age of women	27.2	28.6	29.1	29.7	0.0001
Mean age of household head	41.0	41.4	42.5	42.5	0.2583
Mean household size	8.0	7.8	6.8	6.13	0.0000
Mean percent of children under 5 years	32.1	33.9	31.4	32.9	0.1697
Percent of married women	95.0	95.9	91.3	93.9	0.8080
Percent of women who decide alone on income	86.0	77.0	67.0	66.0	0.4064
Mean age of children in months	17.7	17.6	16.7	17.1	0.6437
Percent of female children	51.2	51.7	46.7	49.9	0.7441

Table 11. Comparison of determinants of child nutritional status across urban agroecological zones (continued)

Proximal variables	Sudano Sahelian	Guinea savannah	Derived savannah	Humid forest	P value
Mean number of antenatal care visits	4.1	5.1	6.1	7.8	0.0000
Percent of women who had at least one antenatal visit	59.8	71.5	77.2	79.5	0.0001
Percent of women who had at least four antenatal visits	74.1	86.1	87.3	88.5	0.0273
Percent of women who delivered at medical facility	28.2	43.0	70.9	79.8	0.0001
Mean birth order	4.2	4.2	3.5	3.5	0.0000
Mean BMI	22.3	23.8	23.2	25.2	0.0000
Percent of women underweight	15.4	10.5	7.3	7.1	0.2728
Percent of children ever vaccinated	63.4	66.5	80.7	82.5	0.0004
Percent of children sick two weeks prior to survey	53.5	42.2	33.3	25.1	0.0001
Percent of women who initiated breastfeeding within 1 hour of birth	31.1	37.7	37.4	29.6	0.2014
Percent of children reached with vitamin A supplement	25.3	40.1	50.0	60.7	0.0001
Percent of children who had BCG vaccination	44	66	74.6	82.5	0.0001
Mean dietary diversity for children:					
6-11 mo	1.9	2.2	2.4	3.2	0.03
12-23 mo	3.6	3.6	3.1	3.7	0.44
24-36 mo	3.4	3.3	3.0	3.7	0.17
24-36 mo (nbf)	4.2	4.0	3.5	4.2	0.22
Percent of children:					
6-11 mo fed at least 2 times/d	63.0	53.2	53.3	70.7	0.40
12-23 mo fed at least 3 times/d	56.3	43.8	65.2	57.1	0.34
24-36 mo fed at least 3 times/d	71.5	75.0	84.1	86.5	0.16
24-36 mo fed at least 4 times/d (nbf)	16.0	41.4	47.4	45.0	0.002
Percent of children fed minimum acceptable diet:					
6-11 mo	18.5	12.8	23.3	39.0	0.18
12-23 mo	35.0	29.2	34.8	34.3	0.95
24-36 mo	39.4	40.0	37.8	48.6	0.52
24-36 mo (nbf)	12.5	26.0	26.3	30.0	0.22

Table 12. Determinants of child malnutrition across rural areas of the geopolitical zones (OLS Regression)

Variables	North Central	North East	North West	South Region	All Rural
Humid forest				0.300	
Sudano-Sahel		-0.869*	-0.345*		-0.380
Guinea savannah	-0.150	0.837*			-0.089
Household economic status	-0.00001	0.0003*	0.0003	0.0002*	0.0003*
Female headed-household	-0.262	0.042	-0.372	0.285	-0.000
Age of household head	-0.014	-0.006	0.004	-0.003	0.018
Household size	0.068	0.009	-0.122	0.014	0.098
Percent of children under 5	0.005	0.008	-0.004	-0.005	-0.005
Household head works in agriculture	-0.31*	0.147	-0.090	-0.612*	-0.057
Woman works for income	0.514*	0.184	1.204*	0.443	0.419*
Age of woman	0.044*	0.078*	0.020	0.022	0.040*
Woman's education: primary	-0.030	-0.242	-0.480	-0.028	0.419
Woman's education: secondary	0.539	-0.348	-0.080	-0.084	0.040
Number of antenatal visits	0.018	0.007	0.015	0.095*	-0.164*
Child had BCG vaccination	0.080	0.285	0.160	-0.245	0.040
Whether woman is literate	-0.341	0.153	0.150	-0.118	-0.006
Whether woman is married	-0.939*	-0.310	1.035	-0.420	-0.361
Woman decides alone on earning	-0.448	-0.003	0.331	-0.240	-0.097
Age of child in months	-0.060*	-.098*	-0.088*	-0.052*	-0.076*
Female child	0.418*	0.229	0.219	0.367*	0.285*
Household squared	-0.002	-0.002	0.004	-0.002	0.001
Birth order of child	-0.075	-0.116*	-0.024	-0.005	-0.464
Derived savannah					0.373
North Central					-0.567
North Central					-0.361
North West					-0.950*
South East					-0.382*
South West					-0.843*
N	286	366	491	92	1500
R squared	0.24	0.36	0.22	0.21	0.29

*Significant at 10 percent and above.

Table 13. Determinants of child malnutrition across urban areas of the geopolitical regions (OLS Regression)

Variables	North Central	North East	North West	South Region	All urban
Humid forest				-0.009	
Sudano Sahelian savannah		-0.682*	-0.215		0.541
Guinea savannah	-0.130	-0.484			-0.336
Household economic status	0.0001	0.0003*	0.0006*	0.0003*	0.0003*
Female-headed household	0.218	-0.035	0.652	0.454	0.220
Age of household head	0.005	0.002	0.012	-0.013	-0.007
Household size	0.340*	-0.010	-0.058	0.333*	0.060
Percent of children under 5	0.015	-0.016	-0.002	-0.006	-0.008
Household head works in agric	-0.380	-0.075	0.100	0.138	0.135
Woman works to earn income	-0.081	0.201	-0.268	0.574	0.340
Age of woman	-0.015	0.026	0.043	0.007	0.022
Woman education: primary	1.065*	0.126	1.290*	0.004	0.407*
Woman education: secondary	0.1008	0.762*	1.153*	0.092	0.544*
Number of antenatal visits	0.036	0.042	-0.051	0.015	0.007
Child had BCG vaccination	-0.037	-0.180	-0.162	0.405	0.057
Whether woman is literate	-0.448	-0.560	-0.942*	0.061	-0.397*
Whether woman is married	0.324	0.044	0.260	-0.368	-0.187
Woman decides alone on earning	0.062	-0.074	-0.067	-0.316	-0.115
Age of child in months	-0.061*	-0.010*	-0.058*	-0.054*	-0.066*
Female child	0.150	0.075	0.117	0.105	0.010
Household squared	-0.014*	0.003	0.002	-0.021*	-0.003
Child birth order	-0.035	-0.044	-0.069	0.034	-0.336
North Central					0.013
North East					0.241
North West					-0.192
South East					0.082
South West					-0.400*
N	158	224	177	255	903
R squared	0.33	0.33	0.17	0.17	0.21

Table 14. Determinant of child malnutrition across rural areas of the agroecological zones (OLS regression)

Variables	Sudano-Sahelian	Guinea savannah	Derived savannah	Humid forest
Household economic status	0.0004*	0.0003	0.0002	0.0002*
Female-headed household	-0.424	0.007	-0.260	0.450
Age of household head	0.001	-0.000	-0.010	-0.007
Household size	-0.066	-0.100	0.140*	-0.041
Percent of children under 5	-0.004	-0.001	0.010	-0.010
Household head works in agric	-0.101	0.126	-0.290	-0.624*
Woman works to earn income	0.782*	0.5928*	0.400	0.227
Age of woman	0.340	0.0608*	0.022	0.045
Woman education: primary	-0.642*	0.245	-0.472*	0.439
Woman education: secondary	-0.435	0.692*	-0.204	0.583
Number of antenatal visits	0.008	0.018	0.023	0.014
Child had BCG vaccination	0.664*	0.084	-0.280	-0.163
Whether woman is literate	0.379	-0.613*	0.300	-0.220
Whether woman is married	1.401*	-0.900*	-1.040*	-0.214
Woman decides alone on earning	0.490*	-0.573*	-0.150	-0.164
Age of child in months	-0.010*	-0.086*	-0.045*	-0.061*
Female child	0.208	0.275*	0.483*	0.281
Household size squared	-0.000	0.004	-0.005	0.001
Child birth order	-0.036	-0.104*	-0.041	0.030
N	425	499	324	252
R Squared	0.27	0.31	0.19	0.19

Table 15. Determinants of child malnutrition across urban areas of the agroecological zones (OLS Regression)

Variables	Sudano Sahelian savannah	Guinea savannah	Derived savannah	Humid forest
Household economic status	0.0004*	0.0003	0.00009	0.0003*
Female-headed household	0.115	0.800	0.118	0.205
Age of head of household	0.001	0.011	-0.005	-0.023*
Household size	-0.031	0.024	0.118	0.511*
Percent of children under 5	0.004	-0.021*	-0.009	-0.007
Head of household works in agriculture	0.753*	0.0230	-0.074	-0.327
Woman works to earn income	0.133	0.113	0.087	1.190*
Age of woman	0.0249	0.006	0.020	0.023
Woman's education: primary	0.816*	0.181	0.425	-0.182
Woman's education: secondary	0.455	0.870	0.025	0.447
Number of antenatal care visit	-0.009	0.015	0.004	0.008
Child had BCG vaccination	0.038	-0.359	-0.010	0.238
Whether woman is literate	-0.487	-0.460	-0.028	-0.446
Whether woman is married	-0.072	0.171	0.393	-0.618
Woman decides alone on earning	0.245	-0.330	-0.133	-0.324
Age of child in months	-0.075*	-0.064*	-0.083*	-0.048*
Female child	0.0860	-0.111	0.190	0.156
Household size squared	0.002	-0.003	-0.006	-0.028*
Child birth order	-0.054	-0.024	-0.065	-0.390
N	241	193	223	246
R Squared	0.25	0.19	0.24	0.19

*Significant at 10 percent level and above.

Table 16. Determinants of maternal nutrition across rural areas of the geopolitical zones (OLS regression)

Variables	North Central	North East	North West	South Region	All rural
Derived savannah					-.345
Humid forest				1.036*	
Sudano Sahelian savannah		-1.285*	-1.21*		-1.88*
Guinea savannah	-0.887*	-1.15*			-1.15*
Household economic status	0.0007*	0.0007	0.0004	0.00001*	0.0009*
Female-headed household	0.021	0.252	0.705	0.100	.0198
Age of household head	-0.023	0.019	0.011	0.041*	.0146*
Household size	0.048	-0.031	-.0035	-0.069	-.035
Percent of children under 5	-0.036*	-0.024*	0.0111	-0.007	-0.0098*
Household head works in agriculture	-0.315	0.141	-0.0777	-0.104	.0215
Woman works to earn income	-0.195	1.303*	0.739	0.95*	.621*
Age of woman	0.013	-.0126	0.098*	0.025	.037*
Woman's education: primary	0.032	.4004	-0.206	-0.143	.042
Woman's education: secondary	.0364	1.954*	-0.136	0.452	.611
Whether woman is literate	0.513	1.29*	1.11*	0.548	.699*
Whether woman is married	0.035	0.131	-0.028	0.800	.425
Woman decides alone on income	0.916	-1.295*	0.041	-0.531	-.320
Parity	0.150	0.197*	-0.043	0.089	.089*
Distance as health care constraint	0.227	-0.254	-0.517*	-0.231	-.265*
Age at first birth	0.131	0.0817	-0.131*	-0.056	-.004
Woman has final say on marriage	0.769	-0.052	0.356	0.528	.506*
North Central					.93
North East					.29
North West					.64
South East					-.072
South West					-1.06
N	4 57	571	828	801	
R squared	0.12	0.18	0.14	0.14	

* Significant at 10 percent and above.

Table 17. Determinants of maternal nutrition in urban areas of the geopolitical regions (OLS regression)

Variables	North Central	North East	North West	South	All Urban
Derived savannah					-0.911*
Humid forest				1.232*	
Sudano Sahelian savannah		-1.21	-1.34		-1.70*
Guinea savannah	.342	-1.09			-.961
Household economic status	.0000*	5.57	.000*	0.00002*	.0000*
Female-headed household	.245	.771	1.38	0.642	.511
Age of household head	.028	.343	.019	-0.017	.0001
Household size	-.117*	-.047	.061	-0.052	-.034
Percent of child under 5	-.018	-.012	.017	-0.010	-.007
Household head works in agric	-1.12*	-.628	.682	-0.206	-.265
Woman works for income	.983	1.041	-.235	0.276	.067
Age of woman	.108	.125*	.082	0.108*	.122*
Woman's education: primary	2.08*	.763	-.432	-0.402	.0996
Woman's education: secondary	2.52*	.010	-2.24	0.004	.071
Whether woman is literate	-.917	.945	.675	0.556	.387
Whether woman is married	.773	-.493	-.226	-1.278*	-.612
Woman decides alone on earning	.933	-.199	-1.21	-0.384	-.075
Parity	.099	-.131	.018	0.236	.0578
Distance constraining health care	-.261	-.083	-.048	0.267	-.185
Age at first birth	-.134	.022	-.007	0.011	-.018
Woman has final say on own health	.444	-.666	1.036	-0.436	-.190
North Central					.534
North East					.244
North West					.326
South East					239
South West					-1.41*
N	293	317	302	728	1640
R Squared	0.23	0.14	0.17	0.20	0.19

*Significant at 10 percent and above.

Table 18. Determinants of maternal nutrition in rural agroecological zones (OLS Regression)

Variables	Sudan – Sahelian savannah	Guinea savannah	Derived savannah	Humid forest
Household economic status	7.41*	7.24*	.00001*	.00001*
Female-headed household	.536	.137	.433	-.283
Age of household head	.002	.010	.0004	.038*
Household size	-.066	.013	.029	-.062
Percent of children under 5	.007	-.023*	-.012	-.012
Household head engaged with agric	-.124	.196	.004	-.278
Whether mother works for income	.214	1.18*	.334	.563
Age of woman	.058*	.024	.019	.039
Woman's education: primary	-.227	.365	.481	-.558
Woman's education: secondary	1.04	1.22*	.339	.376
Whether woman is literate	.911	.804*	.262	.495
Whether woman is married	.853	-.467	-.318	.939
Woman decides alone on earning	-.165	-.757	-.495	.236
Parity	.053	.108	.222	.017
Distance as constraint to health care	-.308	-.326	.420	-.539
Age at first birth	-.059	.052	.015	-.069
Woman has final say on own health	.197	-.036	.674*	.362
N	727	783	589	558
R-squared	0.09	0.15	0.09	0.14

*Significant at 10 percent and above.

Table 19. Determinants of maternal malnutrition in urban areas of the agroecological zones (OLS regression)

Variables	Sudano-Sahelian savannah	Guinea savannah	Derived savannah	Humid forest
Household economic status	.0000*	.0000*	.0000*	.0000*
Female-headed household	1.058	-.002	.401	.971
Age of woman	.046	.037	.015	-.032*
Household size	-.005	-.119	-.026	-.078
Percent of children under 5	.019	-.018	-.014	-.007
Household head works in agriculture	.952	-2.04*	-.463	.464
Woman works to earn income	.1.21	.850	-.653	.207
Age of woman	.114*	.085	.1552*	.110*
Woman's education: Primary	-.052	.438	1.99*	-.812
Woman's education: secondary	-1.28	.125	2.212*	-.435
Whether woman is literate	.912	-.046	-1.026	.983
Whether woman is married	-.539	1.001	-1.23*	-.240
Woman decide alone on earning	-.527	-.018	-.568	-.036
Parity	-.121	.102	.055	.242
Distance as constraint to health care	-.552	-.536	.790*	.235
Age at first birth	-.121	.131	-.085	.005
Woman has final say on own health	.875	1.005	-.177	-.204
N	400	283	452	505
R-Squared	0.15	0.17	0.19	0.20

*Significant at 10 percent and above.

Table 20. Simple Summary of major determinants of child malnutrition across rural areas of the geopolitical regions and AEZs

Variables	North Central	North East	North West	South Region	Sudano-Sahelian	Guinea savannah	Derived savannah	Humid forest zone	All Rural
Household economic status		+		+	+			+	+
Female-headed Household									
Age of household head									
Household size							+		
Household size squared									
Percent of children under five									
Household head primarily engaged with agriculture	x			x				x	
Whether mother earns income	+		+		+	+			+
Age of mother	+	+				+			+
Mother having primary education					x		x		
Mother having secondary education						+			
Having antenatal care visits				+					x
Child having BCG immunization					+				
Maternal literacy						x			
Mother being married	x				+				
Mother deciding alone on earning					+	x			
Age of child in months	x	x	x	x	x	x	x	x	x
Being a female child	+			+		+	+		+
Child birth order		x				x			

Table 21. Simple summary of major determinants of child malnutrition across urban areas of the geopolitical regions and AEZs

Variables	North Central	North East	North West	South Region	Sudano-Sahelian	Guinea savannah	Derived savannah	Humid forest zone	All Urban
Household economic status		+	+	+	+			+	+
Female-headed household									
Age of household head								x	
Household size	+			+				+	
Household size squared	x			x				x	
Percent of children under five						x			
Household head primarily engaged with agriculture					+				
Whether mother earns income								+	
Age of mother									
Mother having primary education	+		+		+				+
Mother having secondary education		+	+						+
Having antenatal care visits									
Child having BCG immunization									
Maternal literacy			x						x
Mother being married									
Mother deciding alone on earning									
Age of child in months	x	x	x	x	x	x	x	x	
Being a female child									
Child birth order									

Table 22. Simple summary of major Determinants of maternal nutrition across rural areas of the geopolitical regions and AEZs

Variables	North Central	North East	North West	South Region	Sudano-Sahelian	Guinea savannah	Derived savannah	Humid forest zone	All Rural
Household economic status	+			+	+	+	+	+	+
Female-headed household									
Age of household head				+				+	+
Household size									
Household size squared									
Percent of children under five	x	x				x			x
Household head primarily engaged with agriculture									
Whether mother earns income		+		+		+			+
Age of mother			+		+				+
Mother having primary education									
Mother having secondary education		+				+			
Maternal literacy		+	+			+			+
Mother being married									
Mother deciding alone on earning		x							
Parity		+							+
Distance to health care			x						x
Age at first birth			x						
Having final say on own health							+		+

Table 23. Simple summary of major determinants of maternal nutrition across urban areas of the geopolitical regions and AEZs

Variables	North Central	North East	North West	South Region	Sudano-Sahelian	Guinea savannahh	Derived savannah	Humid forest zone	All Urban
Household economic status	+		+	+	+	+	+	+	+
Female-headed household									
Age of household head								x	
Household size	x								
Percent of children under five						x			
Household head primarily engaged with agriculture	x								
Whether mother earns income									
Age of mother		+		+	+		+	+	+
Mother having primary education	+						+		
Mother having secondary education	+						+		
Maternal literacy									
Mother being married							x		
Mother deciding alone on earning									
Parity									
Distance to health care							+		
Age at first birth									
Having final say on own health									

Table 24. Typologies of vulnerability to malnutrition based on child and women OLS regression models and comparisons of level of determinants across regions and agro zones

S/No	Major factors of vulnerability to undernutrition	Location by geopolitical, agroecological and place of residence
1	A young male child growing out of infancy or younger than 3 years, having a teen (or relatively young) mother, and residing especially in rural North West, South West and South East, having a mother who does not work to earn income, being in a poor household; Women with no final say on their health, who consider distance to healthcare a challenge, who are not literate, with no primary education, who are relatively young and do not work, being in household with high percentage of children under five, having relatively young household head, being in a poor household, living especially in Sudano Sahelian savannah and Guinea savannah zones.	General rural settings
.	A young child growing out of infancy or child less than 3 years old, mother having neither primary nor secondary education, being in a poor household, residing in urban South West; for the mother: Being a relatively young woman,	General urban settings
3	A young male child growing out of infancy or child less than 3 years old ;having a household head primarily involved with agriculture; having a relatively young mother, and who does not work to earn income; For woman; having high percentage of children under five.	Rural North Central
4	A young child growing out of infancy or child less than 3 years old , being in a large family, mother not having primary education ; For woman: Woman not having primary or secondary education, household being engaged primarily with agriculture.	Urban North Central
5	A young child growing out of infancy or child less than 3 years old, having a high birth order, having relatively young mother, residing in Sudano Sahelian or Guinea savannah parts of the region, being in a poor household. For Woman: high parity, not literate, no secondary education, does not work, high percentage of children under five, residing in Sudano Sahelian and Guinea savannahs.	Rural North East
6	A young child growing of infancy or child less than 3 years, having mother without secondary education, being in a poor household, residing in Sudano Sahelian part of the region; For woman: being relatively young.	Urban North East
7	A young growing child, having a mother who does not work to earn income, residing in the Sudano Sahelian part of the region; For woman: distance to health care, not literate, relatively young, residing in Sudano Sahelian savannah.	Rural North West
8	A young growing child, mother having no primary or secondary education, being in poor household. For woman: No particular factor is indicated.	Urban North West
9	A young male child growing out of infancy or younger than 3 years; Having a household head primarily engaged with agriculture and living in a poor household; For woman: being in a poor household, woman not working to earn income with a relatively young household head.	Rural South region
10	A young growing child, being in a poor household, relatively large household size; For mother: being in a poor household, being a relatively young mother.	Urban South region

Table 24: Typologies of vulnerability (continued)

S/No	Major factors of vulnerability to undernutrition	Location by agroecological and place of residence
11	A young child growing out of infancy or less than 3 years old, having mother who does not take decision alone on earned income, mother that is not married, child not reached with BCG vaccination, mother not working to earn income, being in a poor household; For woman: Relatively young age, being in poor household.	Rural Sudano Sahelian zone
12	A young child growing out of infancy or less than 3 years old, mother not having primary education, household head not being involved in agriculture, being in a poor household; For Woman: being relatively young.	Urban Sudano Sahelian zone
13	A young male child growing out of infancy or less than 3 years old, having high birth order, having mother without secondary education, having a relatively young mother, having mother that does not work to earn income, Woman: not literate, without secondary education, not working; having high percentage of children under five, being in a poor household.	Rural Guinea savannah
14	A young child growing out of infancy or less than 3 years old, being in household with high percentage of children under five; For woman: household head being primarily engaged with agriculture.	Urban Guinea savannah
15	A young male child growing out of infancy or less than 3 years old, mother not having primary education, relatively low household size; Woman having no final say on health.	Rural derived savannah
16	A young child growing out of infancy or less than 3 years old; For woman, not having secondary or primary education, being relatively young.	Urban derived savannah
17	A young child growing out of infancy or less than 3 years old, having household head primarily involved agriculture, being in a poor household; Woman having relatively young head of household.	Rural humid forest
18	A young child growing out of infancy or less than 3 years old, being in a large family, having mother who does not work for income, having a household head that is not young, living in a poor household; For woman: relatively young age, relatively old household head.	Urban humid forest

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