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# Fuel choice, acute respiratory infection and child growth in Uganda

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FUEL CHOICE, ACUTE RESPIRATORY INFECTION AND CHILD GROWTH IN UGANDA

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To

My special Mother, Mrs. Iruka Aghasili; and my beloved Daughter, Desiree Chidumeje.

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# ABSTRACT

Aghasili Onyekachi U. M.S., Purdue University, May 2015. Fuel Choice, Acute Respiratory Infection and Child Growth in Uganda. Major Professor: Gerald Shively.

This thesis seeks to explain the relationship between a household's choice of fuel and the health and nutrition outcomes of children below the age of 5 in Uganda. The first objective is to examine the association between the choice of fuel and the incidence of acute respiratory infection (ARI). The second objective is to measure the relationship between choice of fuel, ARI and nutrition outcomes of children.

I use data from the 2006 and 2011 Uganda Demographic and Health Surveys (UDHS). The total number of observations is 4,463. Data indicate that 94% of rural households in the DHS sample use firewood and 6% use charcoal. In contrast, 22% of urban households use firewood and 76% use charcoal. Approximately 30% of children in the rural sample experience ARI symptoms compared with 20% of children in the urban sample. Both the composite index of anthropometric failure (CIAF) and the conventional Waterlow indicators are used to measure the prevalence of malnutrition. These indicators show a 35% prevalence of stunting, a 6% prevalence of wasting and a 15% prevalence of underweight in the pooled sample. Based on the CIAF, 40% of children in the pooled sample are malnourished. Results from multivariate regressions suggest that the use of firewood is positively correlated with the probability of both ARI, stunting and CIAF.

However, from a statistical perspective, the results suggest that much of this effect can be explained by household factors such as wealth and urban residency. Living in an urban area is observed to be beneficial to health and nutrition outcomes. Wealth is an important factor in explaining patterns of malnutrition. Child's age is negatively correlated with the probability of ARI and positively correlated with the probability of malnutrition. There is a negative correlation between being a male child and the probability of malnutrition. A mother's education and age are negatively correlated with the health and nutrition outcome of the child. Household demographics such as size is positively correlated with health and malnutrition outcome.

# CHAPTER 1. INTRODUCTION

## 1.1 Introduction

Uganda is a landlocked East African country with a total area of 241,038km$^2$ (CIA, 2014). Uganda borders Kenya to the east, Tanzania to the south, Rwanda to the southwest, the Democratic Republic of Congo to the west and South Sudan to the north. Since attaining its independence in 1962, Uganda's economy has grown slowly. This is partly due to civil and military unrest (Uganda DHS, 2011). Agriculture is a major part of Uganda's Gross Domestic Product (GDP) and it employs more than three-quarters of the country's population (IFPRI, 2012). Uganda's population is about 36 million and it is growing at a rate of 3.24%. The fertility rate is 6 children per woman and the total infant mortality rate is 61 deaths per 1000 live births. The rural area is home to about 84% of the Ugandan population.

## 1.2 Setting

In most developing countries, there are numerous disparities between rural and urban settings. These disparities include differences in household socioeconomics, child health and nutrition. Studies show that an urban child is more likely to have a better nutrition outcome than a rural child (Smith et al., 2005; Menon et al., 2001; Sahn and Stifel, 2003). Some studies attribute this disparity to socioeconomic differences between locations. These studies suggest that a socioeconomic improvement is crucial to tackling the disparity between the living settings of urban and rural households (Srinivasan et al., 2013; Pörtner, 2013). One potential factor that has received little attention is the influence of the household's choice of fuel on health and nutrition outcomes. Understanding this relationship might help in explaining the observed disparities between rural and urban health and nutrition outcomes.

### 1.3 Fuel Choices

Wood fuel is a major source of energy for cooking and heating in developing countries.[1] About 75% of the total population in these regions rely on energy derived from wood fuel (Arnold and Jongma, 1978; DeLucia, 1980; Bruce et al., 1998). Between 1992 and 2013 an average of approximately 552 million $m^3$ of wood fuel was used annually in Africa (FAO, 2013). Domestic uses, such as cooking or boiling water over open fires, and home heating during cold periods, constitute about 80% of total wood use (Arnold and Jongma, 1978; DeLucia, 1980; Bruce et al., 1998).

In some countries, and particularly in Uganda, high demand for wood fuel combined with forest loss and other changes in land use, has reduced the supply of high quality biomass and led households to resort to using lower quality biomass, which is typically harvested from farmlands and fallows (Jagger and Shively, 2014). Between the two major sources of wood fuels in Uganda, charcoal and firewood, firewood is considered to be of lower quality. There are two main reasons for this. First, firewood tends to have a higher moisture content compared to charcoal. Second, firewood often

[1] Wood Fuel generally refers to energy derived from woody biomass which in this case refers to firewood, charcoal, crop residue, animal dung and wood pellets (May-Tobin, 2011).

requires the use of uncontrolled combustion techniques. Studies indicate that wet fuels and uncontrolled combustion techniques are both associated with higher particle emission (Johansson et al., 2003). The incomplete combustion of this lower quality biomass, including straw and crop residue, can create high exposure to respirable particles and other health hazard gases such as carbon monoxide, formaldehyde, nitrogen oxides, and polyaromatic hydrocarbons (Pandey et al., 1989; Jagger and Shively, 2014; Boleij and Brunekreef, 1989; Smith, 2006; Kvist, 2012). The body has an effective mechanism of eliminating particulate matter that is larger than 10 microns in diameter. However, research indicates that particles from firewood smoke have very small diameters, less than 2.5 microns (Bølling et al., 2009). The size of these particles allows for an easy access to the lungs where it collects and causes damage.[2] Studies have shown that women and children in these regions are at higher risk of exposure to these harmful particles and gases, due to the major role they play in carrying out domestic activities in confined spaces (Pandey et al., 1989; Smith, 2006; Jagger and Shively, 2014; Sharma et al., 1998).

In Uganda, approximately 41million $m^3$ of non-commercial wood fuel was produced in 2012 compared to 19 million in 1970 (FAO, 2013). Of this amount, charcoal accounted for about 980 thousand tonnes in 2012. Wood fuels are typically burned on traditional stoves in confined unventilated spaces by women and young children carrying out daily domestic activities.[3]

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[2] Particles emitted and the damages associated with these particles, depend on the condition of combustion and the combustion appliance (Johansson et al., 2004; Bølling et al., 2009)

[3] A typical traditional stove in sub-Saharan Africa has a base of three large stones with the energy source tucked between and an open fire rising above (Smith, 2006).

Various interventions have advocated for the use of modern stoves. Three main rationales for these interventions are: (1) improved stove eliminates the inconveniences associated with the collection and combustion of wood fuels; (2) the use of an improved stove is likely to reduce the local demand for and price of wood fuel and; (3) the switch to improved stoves is likely to decrease deforestation (Manibog, 1984). Despite these interventions, a majority of households in Uganda, still rely heavily on wood fuels as the primary source of energy.

Several economic studies link the level and choice of wood fuel consumption to the household's level of income (Arnold et al., 2006; Barnes et al., 2004). These studies support the hypothesis of the "energy ladder" that suggests that the consumption of wood, an inferior and low-cost fuel, generally decreases as income rises. Similarly, urbanization, household size and proximity to wood fuel sources have been identified as important determinants of the household's choice of fuel (Arnold et al., 2006; Barnes et al., 2004; Jagger and Shively, 2014). Urbanization typically leads households to substitute charcoal for firewood. Household size also has a positive influence on the preference for firewood (Arnold et al., 2006; Barnes et al., 2004; Jagger and Shively, 2014).

Multiple indirect costs are associated with the type of fuel a household decides to use. As mentioned earlier, impaired health is an important part of cost, although this is typically hidden. Studies suggest that a household that uses lower quality forms of biomass spends approximately 55 percent more, annually, on health care than households that use modern fuels (Pant, 2012; Habermehl, 2007). Aside from the obvious monetary costs of health care, implicit costs resulting from illness include time not spent on income generating activities and domestic activities.

### 1.4 Acute Respiratory Infection and Malnutrition.

Acute respiratory infection (ARI), which was associated with about 4 million deaths in 1990, is a leading cause of death for children below the age of 5 in developing countries (Kirkwood,1995; Boleij and Brunekreef, 1989; Ezzati and Kammen, 2001; Pandey et al., 1989; Parashar et al., 2003; Stanek et al., 1994). Studies have found a significant positive association between episodes of ARI and the level of smoke exposure, particularly in children (Pandey et al., 1989; Jagger and Shively, 2014; Ezzati and Kammen, 2001; Armstrong and Campbell, 1991; Awasthi et al., 1996). The deterioration of immune responsiveness as a result of inhaling smoke may contribute to ARI in infants and children, and an already malnourished child is likely to be at higher risk of ARI (Pandey et al., 1989).

Using the Uganda DHS 2000/01 data, Sansa (2005) finds an ARI prevalence of 18% for children below the age of 5. Based on logit analysis, he suggests that smoke exposure increases the odds of an ARI episode. He also finds a significant association between ARI episodes and household living standards (Sansa, 2005). A more recent, but smaller study from Uganda suggests an ARI prevalence of about 34% for children below the age of 5 (Jagger and Shively, 2014). Based on probit analysis on survey data collected using questions replicated from the Uganda DHS, Jagger and Shively (2014) find significant interactions between quantity and quality of biomass used and ARI episodes. They suggest that lower quality biomass fuel is associated with a higher likelihood of ARI episodes, particularly in children.

Malnutrition in children below the age of 5 is another leading cause of death and an important concern in developing countries.[4] Stunting and wasting are conventionally used as indicators of chronic and acute malnutrition, respectively (WHO, 1995). Stunting results from perpetual lack of food or nutrients, as well as disease, whereas wasting is a representation of the immediate results of reductions in food and nutrient intake (Nandy et al., 2005). Underweight can result from stunting and or wasting. In 2011, 165 million children below the age of 5 were stunted worldwide, 52 million were wasted and 101 million were underweight (UNICEF et al., 2012; Onis et al., 2011). The likelihood of morbidity and mortality among children below the age of 5 rises with ARI episodes and low weight-for-age, weight-for-height and or height-for-age (Pandey et al., 1989; Tupasi et al., 1990; Etiler et al., 2002; Smith et al., 1991).

There is a high prevalence of malnutrition in the eastern region of Africa. In 2011, 22.8 million children below the age of 5 were stunted, 3.6 million were wasted and 10.4 million were underweight (UNICEF et al., 2012). In Uganda, 33 percent of children below the age of 5 in 2011 were stunted, 5 percent were wasted and 14 percent were underweight (Uganda DHS, 2011).

Epidemiologic studies have mainly focused on finding a causal relationship between indoor air pollution and ARI (Ezzati and Kammen, 2001; Armstrong and Campbell, 1991; Awasthi et al., 1996; Sharma et al., 1998). Other studies have focused either on wood fuel shortages as they relate to deforestation or have simply looked at the

[4] Child malnutrition is commonly measured using anthropometric indices. A child is classified as either stunted, wasted or underweight if their height-for-age, weight-for-height or weight-for- age, respectively, is more than 2 standard deviations below the NCHS/WHO growth reference median (WHO 1995)

effects of biomass fuel consumption on the general household health outcome (Arnold and Persson, 2003; Jagger and Shively, 2014). The effects of household fuel choices on child nutrition outcomes remains poorly understood.

## 1.5 Objectives

The primary objective of this thesis is to contribute to knowledge on ARI and child health. I use data from the 2006 and 2011 Uganda DHS. A series of multivariate regressions are estimated that account for socioeconomic factors, health and nutrition factors, environmental factors and wood fuel choices. First, I examine the association between the choice of fuel and ARI incidence. This is done through a series of multivariate regressions using an ARI episode as a dependent variable and smoke exposure as an explanatory variable. Studies have shown household size to be important determinant for the choice of fuel (Mekonnen and Köhlin, 2008; Barnes et al., 2004). Therefore, in this study, household size and the cooking setting serve as proxies for smoke exposure.[5] I hypothesize that household size and cooking setting indicate smoke exposure, which in turn influences the risk of ARI.

The second objective focuses on measuring the relationship between household choice of fuel and a child's nutrition outcome. I measure the association between a household's fuel choice and the conventional Waterlow indicators of malnutrition (HAZ and WHZ) and also the correlation between a household's fuel choice and the composite

[5] Following Jagger and Shively (2014), the cooking setting is defined by whether food is cooked on a stove or over an open fire; in the house, in a separate building or outdoors; and whether the household has a chimney, hood or neither.

index of anthropometric failure (CIAF). I hypothesize that the household’s fuel choice is positively associated with a child’s nutrition outcome.

# CHAPTER 2. CONCEPTUAL FRAMEWORK AND HYPOTHESES

## 2.1 Conceptual Framework

Several factors directly or indirectly influence the health and nutritional outcome of a child.[6] As presented in Figure 1, factors are grouped into categories; basic determinants, underlying social and economic determinants, underlying environmental, biological and behavioral determinants and immediate determinants. At the basic level, there is the influence of social, political and economic institutions. These institutions govern the availability of adequate infrastructure. The location of a household may play an important role in determining the household's access to available infrastructure. This in turn can influence other environmental, biological and behavioral factors that directly determine health and nutrition outcomes.

## 2.2 Hypotheses

Nine main hypotheses are tested in this thesis, all related to the effect of an observed factor on a child's health and nutrition status. These correspond to smoke exposure, child's age, gender, wealth, experience, education, location, food demand, fuel demand and disease and illness. A synopsis of these hypotheses is provided in Table 1.

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[6] The highlighted areas in the framework are the factors of focus in this thesis.

## 2.3 Explanatory Variables

In this thesis, the explanatory variables are organized into three groups: child characteristics, mother characteristics and household characteristics.

### 2.3.1 Child Characteristics

Studies have shown that a child's demographic characteristics are important determinants of the child's health and nutrition status. One such characteristic is child age. Studies suggest that the nutrition intake within the first 2 years of a child's life is crucial in determining the child's long-term nutritional outcome (Prendergast and Humphrey, 2014; Fishman et al., 2004). This leads us to expect that a child's age will be positively correlated with the prevalence of stunting and the duration of breastfeeding will be negatively correlated with the prevalence of malnutrition. The sex of a child may also play a significant role in the nutritional outcome. Bose et al. (2007) found boys to be significantly heavier than girls. Based on this, we would expect being a girl to be positively correlated with the prevalence of wasting.

The child's health characteristics may also be key determinants of short-term and long-term nutrition outcomes. Studies show that morbidity is strongly associated with malnutrition (Fishman et al., 2004; Caulfield et al., 2006). Based on this, we expect to observe a higher prevalence of malnutrition in a child who has diarrhea, measles or who lacks vitamin A. We also expect that the prevalence of ARI will be positively correlated with the prevalence of malnutrition.

### 2.3.2 Mother Characteristics

Mother's characteristics are also expected to play major role in determining a child's health and nutritional outcome. Studies have directly linked maternal malnutrition to low child birth weight (Villar and Belizan, 1982). We therefore expect a mother's BMI to be negatively correlated with malnutrition. We also expect that a mother's education will be negatively correlated with the prevalence of ARI and malnutrition. This is based on the fact that an educated mother is more likely to be better off in terms of economic status as well as health and nutrition. Similarly, an educated mother is more likely to live in areas with better access to healthcare. Seeing that a mother is usually the primary care giver, we expect that a mother's age will be negatively correlated with the prevalence of ARI and malnutrition. This is based on the assumption that an older mother is more likely to be experienced in managing the home. Mothers' habit also influences the child. We assume that a mother with the habit of smoking cigarettes increases the child's level of exposure to harmful gases. Based on this we expect that smoking cigarettes will be positively correlated with the prevalence of ARI.

### 2.3.3 Household Characteristics

Household characteristics maybe important determinants of a child's health and nutrition outcome. As poverty is said to be the underlying determinant of health and nutrition, we expect wealth to be negatively correlated with the prevalence of ARI and malnutrition (Fishman et al., 2004). The household demographics maybe important factors. We expect that the age of the head of household will be negatively correlated with the prevalence of ARI and malnutrition. This is based on the assumption that older household heads are more mature and better experienced in making good household decisions with respect to household income and expenditure. We expect that a female-headed household will be positively correlated with malnutrition and that the number of females in a household will be negatively correlated with malnutrition. This expectation is based on the assumption that female-headed households are prone to poverty and that having more women in a household helps influence the nutrient intake of the household. Family size tends to be larger in, rural areas, which are often characterized by higher poverty rates, illiteracy rates, inadequate healthcare and a high use of lower-quality biomass fuels. So we expect the number of household members to be positively correlated with the prevalence of ARI and malnutrition.

Location determines access to available resources. So, we expect that living in rural area will be positively correlated with the prevalence of ARI and malnutrition and living in urban area will be negatively correlated with the prevalence of ARI and malnutrition.

The incomplete combustion of lower-quality biomass creates high exposure to respirable particles and other harmful gases (Pandey et al., 1989; Boleij and Brunekreef, 1989). So, we expect for the use of firewood and straw to be positively correlated with the prevalence of ARI. Since wood fuel is a major source of energy for cooking, we expect that it will be positively correlated with the prevalence of malnutrition. We expect that in-house cooking will be positively correlated with the prevalence of ARI and cooking in separate building or outdoor, will be negatively correlated with the prevalence of ARI. Cooking inside a poorly ventilated house, where household members sleep, creates a high exposure to harmful gases. Whereas, cooking outdoor reduces the intensity of the smoke inhaled and cooking in a separate building reduces the duration of exposure to harmful gases.

Sanitation, type of toilet, determines exposure to germs and diseases. Based on this we expect that using improved toilet facilities, as opposed to unimproved toilet facilities, will be negatively correlated with the prevalence of malnutrition. Similarly we expect that collecting drinking water from improved water sources, as opposed to unimproved sources, will be negatively correlated with the prevalence of malnutrition. This is based on the assumption that unimproved water source are mediums for the spread of germs and disease.

# CHAPTER 3. DATA AND DESCRIPTIVE ANALYSIS

## 3.1 Data Source and Construction.[7]

Several variables are needed to study the relationship between household fuel choices and child nutrition outcomes. For this thesis, household and individual data were sourced from the 2006 and 2011 Uganda Demographic and Health Surveys (UDHS). The Demographic and Health Surveys (DHS) were introduced in 1984 and have since been funded by the U.S. Agency for International Development (USAID), participating countries and other donors. The DHS aims at providing information on maternal and child health, HIV/AIDS, malaria, nutrition, fertility, family planning and population demographic trends in over 90 countries.

The 2006 and 2011 UDHS cover all districts of the country. The surveys were conducted by the Uganda Bureau of Statistics (UBOS). 9,864 households were randomly selected to be surveyed in the 2006 UDHS. Occupants were found in only 9,099 of these selected households. 8,870 of these occupied households completed the survey yielding a response rate of 98%. In these households, 8,531 eligible women and 2,503 eligible men were successfully interviewed.[8] In 2006, data were collected on 2,685 children below the

[7] This section relies heavily on data and documents from the 2006 and 2011 UDHS. http://dhsprogram.com/what-we-do/survey/survey-display-399.cfm.
[8] Eligibility is specified as women and men who are between the age of 15-49 and 15-54 respectively. They also had to be permanent residents of the household or a visitor present the night prior to the interview.

age of 5. The sample selection was done in two stages. First, clusters were selected from the 2005/06 Uganda National Household Survey (UNHS) which was selected from the 2002 Census sample frame. Also selections were made from the list of internally displaced persons (IDP) living in camps. Second, households were then selected from the complete list of households in the cluster.

The 2006 UDHS contains three questionnaires: household, women and men. Questionnaires were made available in English and six local languages. The household questionnaire identified eligible women and men, collected basic information, identified characteristics of household's dwelling unit and recorded biometric information. The women's questionnaire collected information on background characteristics, birth history, childhood mortality, family planning methods, vaccinations and childhood illnesses, infant feeding practices, employment information, and a list of others. The men's questionnaire collected similar data to the women's.

The 2011 UDHS is somewhat similar to the 2006. 10,086 households were randomly selected from 2009/10 household clusters which were in turn selected from the 2002 Census sample frame. 9,885 eligible women and 3,628 eligible men were successfully interviewed. The criteria for eligibility remains similar to that in 2006. In 2011, data were successfully collected on 2,336 children aged 5 and under.

A fourth questionnaire was added in the 2011 UDHS: the maternal mortality questionnaire. This questionnaire collected information on maternal mortality. Nevertheless, the other questionnaires were similar to the 2006 questionnaires with exception to the added or removed variables. The gathered information was eventually processed and sorted into different files.

In this thesis, the child is the unit of analysis. The 2006 and 2011 datasets were stacked. Using unique household identifiers, the household and mother datasets were merged onto the child dataset. This provides information that is useful in understanding the interaction between the child, mother and household while keeping the child as the unit of analysis. Observations with missing or flagged nutrition data were dropped. The entire process was done using Stata. The merging and stacking process resulted in 4,463 observations and 692 variables. The socioeconomic, health and nutrition data are of particular interest to this thesis. The socioeconomic data deal with information on household's regional location, size, education, literacy, occupation, wealth, amenities, type and area of residence, religion and general living standards. The health and nutrition data cover information on general health and hygiene practices, illness and disease symptoms, anthropometric measurements and access to available health facilities. The core variables for this thesis are the household fuel choices, location, ARI symptoms and nutrition status.

As part of the household survey, households were asked to identify the type of fuel they used for cooking. The choices provided were: electricity, LPG/natural gas, biogas, kerosene/paraffin, charcoal, firewood, straw/shrubs/grass, animal dung and other. The reports suggest firewood and charcoal as the primary sources of fuel. Out of the 4,463 children observed, 3,680 are from households that primarily used firewood and 750 are from households that primarily used charcoal. As a result, this analysis focuses on a division between firewood and charcoal.[9] For the sake of analysis, two binary variables were created, one each to represent the use of charcoal firewood.

The DHS generally adopts a particular country's definition of urban and rural. For Uganda, urban areas are defined as areas with town, municipal, or city councils (IFPRI 2011). These areas in 2002 ranged from a population of 1,600 to 1.2 million. In this thesis, the reported locations in the UDHS were transformed into a binary variable with 0 representing rural and 1 representing urban.

One of the questions on health required each woman to indicate whether her child had recently experienced fever or cough, particularly within the two weeks prior to the interview. A binary ARI index was created using the combination of these variables. ARI equals 1 if a child experienced fever and cough simultaneously, and 0 if otherwise. As observed, about 1290 children (29% of the sample) had ARI symptoms.

The UDHS collects anthropometric measurements based on the WHO guidelines. These measurements are in turn converted into Z-scores.[10] Distribution of Z-scores are presented in figures 2–4. Based on the WHO child growth standards, for this thesis, the cut-off value is set at <-2 standard deviation to indicate stunting, wasting and underweight (WHO, 2006). A child with a height-for-age Z-score (HAZ) less than 2 standard deviations below the median is classified as stunted. A child with a weight-for-

[9] In this analysis, firewood, straw/shrubs/grass and animal dung are grouped together while charcoal, electricity, LPG/natural gas, biogas and kerosene/paraffin are grouped together. This is done based on the quality of the gases emitted. There are 16 observations for straw/shrubs/grass and there are only 17 observations in total for the other sources of fuel.

[10] Z-scores, also known as standard deviation scores, are widely used for anthropometric analysis.

height (WHZ) less than 2 standard deviations below the median is classified as wasted. A child with a weight-for-age (WAZ) less than 2 standard deviations below the median is classified as wasted. These Z-score variables were in turn used to create a set of composite indexes of anthropometric failure (CIAF) variables. Based on Nandy et al. (2005), groups A, B, C, D, E, F and Y were created. Group A consists of children who are neither stunted nor wasted nor underweight. Group B is made up of children who are wasted but not stunted and underweight. Group C are the children that are wasted and underweight but not stunted. Group D has children that are stunted and wasted and underweight. Group E are the children that are stunted and underweight but not wasted. Group F are the children that are stunted but neither wasted nor underweight. Finally, group Y are the children that are underweight but not stunted and wasted. The proportion of children in each group is shown in Table 2. The proportions from these groups are used to determine the overall prevalence of malnutrition as measured by the CIAF. The formula sub-group proportions sum to 1 by construction:

$$A + B + C + D + E + F + Y = 1 \quad [1]$$

$$CIAF = \frac{1 - A}{(A + B + C + D + E + F + Y)} = \frac{1 - A}{1} = 1 - A \quad [2]$$

Another important determinant included in this thesis is household size. Respondents were asked to specify the number of household members. The reported sizes range from 2 to 22. I use household size as a proxy for the level of smoke exposure. This is based on the assumption that larger households burn more biomass than smaller households. The summary statistics for all variables of interest are presented in Table 3.

## 3.2 Descriptive Analysis.

The two effects of particular interest in this section are the location effect and the choice of fuel effect. Several studies have suggested an inequality in socioeconomics, health and nutrition outcomes between rural and urban areas (USAID, 2011; Fotso, 2007). The bivariate interactions discussed below will help to identify and illustrate such differences. As mentioned earlier, the location variable is a binary index with 0 indicating rural and 1 indicating urban. Taking into account the choice of fuel per location, we see that 94% of rural households and 22% of urban households use firewood, whereas 76% of urban households and only 6% of rural households use charcoal (tables 4 and 5). The Kendall's tau-b test result suggests a negative correlation between choice of fuel and location.

The data show a higher prevalence of ARI among rural children below age 5 in comparison to their urban counterparts. About 30% of children in rural areas experience ARI compared to 20% in urban areas (Table 6). The Pearson chi-square test result suggests a statistically significant relationship between ARI symptoms and location, and Kendall's tau-b test result suggests a negative correlation. Several factors could be contributing to this outcome. One possible explanation, to be tested below, could be linked to the higher rates of firewood use observed in rural areas. The outcomes from the bivariate comparison of nutrition status and location variable indicate that 42% of rural children have an anthropometric failure compared to only 25% in urban areas (Table 7). Similarly, the percentages of children in rural areas that are stunted, wasted and underweight are significantly higher than in urban areas (tables 8-10). The Pearson chi-square and Kendall's tau-b test results suggest a significant and negative relationship between stunting and urban location, and underweight and urban location. The Pearson chi-square test result indicates that there is no statistically significant relationship between wasting and urban location.

To further illustrate the location effect, several bivariate graphs are analyzed. Each variable of interest is plotted against the wealth index factor score (WIFS) and the age of the child (in months). The WIFS is included in the DHS as an indicator of the household's economic status. A lower WIFS is indicative of a poorer household. As seen, for every level of WIFS, the proportion of firewood use is higher in the rural sub-sample than in the urban sub-sample. Also, the proportion of firewood use tends to decrease in both settings as WIFS increases (Figure 5). With charcoal, the level of use increases as WIFS increases. However, for every level of WIFS, there is a higher proportion of charcoal use in the urban sub-sample than in the rural sub-sample (Figure 6). These figures generally support the hypothesis that firewood is as an inferior good. In terms of ARI incidence, there tends to be an increase in probability between the ages of 0 and 9 months with a higher probability observed in rural areas (Figure 7). Similarly, from all indications, poverty is correlated with ARI incidence. Lower WFIS are seen to be associated with a higher proportion of ARI incidence in both rural and urban setting, although these proportions tend to be higher in the rural sample (Figure 8).

The outcomes from the bivariate relationship between malnutrition and location are somewhat similar to those of ARI. As shown, there is a higher rate of anthropometric failure for children below the age of 5 in the rural sub-sample than for their urban counterparts. This rate tends to increase with age until about 30 months after which it gradually decreases. For children in the urban sub-sample, the peak rate is observed at about 21 months (Figure 9). Outcomes from conventional malnutrition indicators do not completely deviate from this pattern (figures 11 and 15). A rather interesting pattern appears for wasting. The rates in urban and rural settings seem to converge at about 28 months and then diverge as rural outcomes deteriorate (Figure 13). Similar to what is observed with ARI, poverty is correlated with anthropometric failure and conventional malnutrition indicators. The rates of anthropometric failure, stunting and underweight tend to decrease as WIFS increases for both locations (figures 10, 12 and 16) whereas that of wasting decrease and then increase as WIFS rises further (Figure 14). These tables and figures almost all have one thing in common, namely an observable difference in outcomes between urban and rural samples.

To better understand the differences observed above, the influence of ARI is analyzed. The bivariate interaction of choice of fuel and ARI indicates that 86% of children below age 5 that suffer from ARI come from households that use firewood, whereas only about 13% come from households that use charcoal (tables 11 and 12). Recall from tables 4 and 5 that the use of firewood is dominant among rural households while the use of charcoal is dominant among urban households. So we could expect to find a higher ARI prevalence in rural than urban areas. Table 12 confirms this expectation. We see that about 89% of children that suffer from ARI are located in rural areas whereas only about 11% are located in urban areas. In terms of the interaction between ARI and a child's malnutrition status, they appear to be positively correlated (tables 14-17).

The bivariate graphs show that the outcomes for children with ARI and those without ARI move in similar directions without much of a difference (figures 17-22).

However, the proportion of wasting and underweight appears to be higher in children below age 5 that suffer from ARI and also for those in households with lower WIFS (figures 23-26). So, if underweight tends to be higher in children with ARI (Figure 25) and ARI tends to be higher in rural areas (Figure 7), then what we observe in Figure 15 is expected.

At this point, the question that remains is, what factors could be influencing these observed outcomes? In order to answer this question, the relationships are further explored using regressions

# CHAPTER 4. MODEL OF FUEL CHOICE AND CHILD NUTRITION OUTCOME

## 4.1 Chapter Overview

Two main questions serve as a preamble to this analysis; (1) is a household's fuel choice associated with the health and nutrition outcome of the child in that household? And (2) if so, could this be a plausible explanation for the difference in nutrition outcomes observed between rural and urban settings?

An ideal approach would be to first analyze the determinants of a households choice of fuel, including the price of fuel and the proximity to forest as instrumental variables. However, no clear and appropriate instruments are available for this approach, so, we directly measure the influence of the choice of fuel on the health and nutrition outcomes, rather than resorting to the use of weak instruments, which can be problematic from an econometric point of view.

As discussed in previous chapters, several factors are involved in determining a household's choice of fuel and a child's nutritional outcome. These factors range from the household's socioeconomic status to the health and nutrition of the household members. As previously identified, a majority of households in rural areas rely on lower quality biomass as the source of fuel in comparison to households in urban areas. Similarly, acute respiratory infection (ARI) and malnutrition are more prevalent in rural areas than in urban areas. This chapter seeks to further explore and explain these patterns.

## 4.2 Empirical Approach

### 4.2.1 Probit Regressions for ARI and Nutritional Status

In order to properly analyze the binomial response variables in this thesis, I use probit regressions. The Uganda Demographic and Health Surveys (UDHS) contains data on households' type of cooking fuel. A new variable (firewood) is created from this information, taking on the value of 1 for wood, straw, shrubs and grass; and 0 otherwise. This variable is used in regressions to indicate a household's choice of fuel. ARI is a dependent variable in this analysis. This binary variable is created from the interaction of various original UDHS health variables and used in probit regressions to indicate that a child exhibited symptoms consistent with acute respiratory infection. Stunting and CIAF are another group of dependent variables in this analysis. The anthropometric measurements, HAZ and WHZ, derived from the UDHS are used to create binary variables, stunting (HAZ <-2) and wasting (WHZ <-2). The combination of these variables are used to create another binary variable, CIAF. These variables are used as dependent variables in series of probit regressions indicating a child's malnutrition status.

There are two sets of probit regressions. The first set of regressions explores the role of child, mother, and household variables in explaining the relationship between ARI and stunting, controlling for fuel choice. The second set of regressions explores the role of similar factors, used in the first set of regression, in explaining the relationship between ARI and CIAF. It is assumed that there is a correlation between the independently distributed error terms of these variables. Based on this assumption, I run series of seemingly unrelated bivariate probit regressions. In other words, the analysis is conducted for two separate regressions simultaneously there by analyzing the effects of cross-equation correlations on the standard errors of the regression coefficients.

The bivariate model is:

$$y_1^* = \beta_1' X_1 + \varepsilon_1, y_1 = \begin{Bmatrix} 1 & if\ y_1^* > 0 \\ 0 & if\ y_1^* \leq 0 \end{Bmatrix}$$

$$y_2^* = \beta_2' X_2 + \varepsilon_2, y_2 = \begin{Bmatrix} 1 & if\ y_2^* > 0 \\ 0 & if\ y_2^* \leq 0 \end{Bmatrix}$$

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix} \sim \mathrm{N}\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}\right]$$

The log likelihood function is:

$$logL = \sum_{i=1}^{n} \log \Phi_2[(2y_{i1} - 1)\mu_1, (2y_{12} - 1)\mu_2, (2y_{i1} - 1)(2y_{i2} - 1)\rho]$$

The estimated models are:

$$ARI = f(FW, CC) \text{ and } Stunting = f(FW, CC) \quad [1a]$$

$$ARI = f(FW, CC, MC) \text{ and } Stunting = f(FW, CC, MC) \quad [1b]$$

$$ARI = f(FW, CC, MC, HHC) \text{ and } Stunting = f(FW, CC, MC, HHC) \quad [1c]$$

$$ARI = f(FW, CC) \text{ and } CIAF = f(FW, CC) \quad [2a]$$

$$ARI = f(FW, CC, MC) \text{ and } CIAF = f(FW, CC, MC) \quad [2b]$$

$$ARI = f(FW, CC, MC, HHC) \text{ and } CIAF = f(FW, CC, MC, HHC) \quad [2c]$$

where FW is type of cooking fuel (1 if firewood or straw or shrubs or grass, 0 otherwise); CC is child characteristics; MC is mother characteristics; and HHC is household characteristics. The overall modelling format allows for comparison across results. In other words, a change in the absolute value of the base regression coefficients reflects the effects of adding these additional factors.

### 4.2.2 Multiple Linear Regression for WHZ

There are not enough observations to effectively examine the factors associated with wasting (WHZ<-2) instead, I examine the factors associated with child z-scores. The continuous nature of the WHZ allows for it to be used as a dependent variable in multi linear regressions. This set of regressions explores the role of child, mother, and household variables in explaining child z-scores, controlling for ARI and fuel choice. The ordinary least squared regression model is:

$y = X\beta + \varepsilon$

The estimated models are:

$WHZ = f(ARI, FW, CC)$ [3a]

$WHZ = f(ARI, FW, CC, MC)$ [3b]

$WHZ = f(ARI, FW, CC, MC, HHC)$ [3c]

# CHAPTER 5. RESULTS AND DISCUSSION

## 5.1 Results

Recall that the objectives of this analysis are to examine the association between a household's choice of fuel and the probability of ARI and malnutrition. The results from the bivariate probit analysis and multiple linear regressions are presented in this chapter.[11]

### 5.1.1 Bivariate Probit Regression Results for Prevalence of ARI and Stunting

The results of the seemingly unrelated bivariate probit regressions for the prevalence of ARI and stunting are reported in Table 18. In order to compare coefficient estimates, results for three separate pairs of regressions are listed. All regressions include the explanatory variable of interest, firewood, and each contains a progressively larger set of control variables starting with child level characteristics, subsequently adding mother characteristics and household characteristics are added subsequently. Results from each regression are reported in paired columns, beginning with the baseline model that includes child level control variables. Only models (1A and 1B). Looking at Model 1, the tetrachoric correlation is not significantly different from zero. This indicates that the probability of ARI and the probability of stunting are not strongly correlated. For this

[11] Year is not controlled for in this analysis. However, this does not affect the results because there is no observed significant difference in outcomes by year.

regression I find a strongly significant and positive relationship between the use of firewood and the probability of both ARI and stunting. There is a strongly significant and negative relationship between the age of the child and the probability of ARI. In contrast, there is a strongly significant and positive relationship between the age of the child and probability of stunting. A strongly significant and negative relationship is observed between the sex of a child (male) and the probability of stunting. The duration of breastfeeding is strongly significant and negatively correlated to the probability of stunting. There is a significant and positive relationship between receiving measles vaccination and the probability of stunting.

Models 2A and 2B add mother characteristics as control variables. The tetrachoric correlation remains not significant and the use of firewood remains strongly significant and positively related to both the probability of ARI and stunting. The child's age remains strongly significant and negatively correlated with the probability of ARI, and strongly significant and positively related with the probability of stunting. Being male remains strongly significant and negatively correlated with the probability of stunting. The duration of breastfeeding remains strongly significant and negatively correlated with the probability of stunting. Controlling for mother characteristics, having received measles vaccination is no longer significant. Mother's education has a strongly significant and negative correlation with probability of stunting.

Models 3A and 3B add household variables to models 2A and 2B. The tetrachoric correlation becomes weakly significant and positive after controlling for these household factors. This suggests that the probability of ARI is correlated with the probability of stunting, and justifies the use of the bivariate probit approach. After controlling for household factors, the use of firewood is no longer significantly correlated with either the probability of ARI or the probability of stunting. Child's age remains strongly significant and negatively associated with the probability of ARI, and strongly significant and positively associated with the probability of stunting. The sex of the child (male) and the duration of breastfeeding remains strongly significant and negatively correlated with the probability of stunting. Measles vaccination becomes strongly significant and positively related with the probability of stunting. Mother's age becomes strongly significant and negatively correlated with the probability of stunting. Mother's education remains strongly significant and negatively correlated with the probability of stunting.

There is a strongly significant and negative relationship between living in an urban area on the one hand and both the probability of ARI and stunting on the other. There is also a strongly significant and negative relationship between altitude and the probability of ARI. However, there is a strongly significant and positive relationship between altitude and the probability of stunting. The wealth quintiles, with the exception of the middle quintile, are strongly significant and negatively correlated to the probability of stunting. However, there is no significant correlation between wealth and the probability of ARI. There is a weakly significant and negative relationship between the age of the household head and the probability of stunting. I find a significant and positive relationship between family size and both the probability of ARI and stunting. There is a strongly significant and negative relationship between cooking in a separate building, compared to cooking indoors, and the probability of stunting.

### 5.1.2 Bivariate Probit Regression Results for prevalence of ARI and CIAF

Table 19 shows the results for three seemingly unrelated bivariate probit regressions for the prevalence of ARI and CIAF. As before, the models with child characteristics (4A and 4B) serve as the baseline regressions. Models 5A and 5B add mother characteristics and models 6A and 6B add household characteristics.

In model 4, the child characteristics model, the tetrachoric correlation is weakly significant and positive, suggesting that the probability of ARI is correlated with the probability of CIAF. I find a strongly significant and positive relationship between the use of firewood and the probability of both ARI and CIAF. I find a strongly significant and negative relationship between a child's age and the probability of ARI but no significant result for age and CIAF. There is a strongly significant and negative relationship between being a male child and the probability of CIAF. The duration of breastfeeding is strongly and negatively correlated with CIAF.

The tetrachoric correlation is not significant in Model 5, which controls for mother's characteristics. The use of firewood remains strongly significant and positively related to the probability of both ARI and CIAF. Similarly, the age of the child remains strongly significant and negatively correlated with the probability of ARI. The age of the child becomes significant and positively correlated with the probability of CIAF. The sex of the child (male) remains strongly significant and negatively correlated with the probability of CIAF. The duration of breastfeeding also remains significant and negatively correlated with the probability of CIAF. There is a strongly significant and negative relationship between a mother's age and the probability of CIAF. There is also a strongly significant and negative relationship between mother's education and the probability of CIAF.

The tetrachoric correlation again becomes significant in Model 6, which controls for additional household factors. The use of firewood becomes insignificant. The age of the child remains strongly significant and negatively correlated with the probability of ARI. Being a male child and the duration of breastfeeding remains strongly significant and negatively correlated with the probability of CIAF. Mother's age and education remain strongly significant and negatively correlated with the probability of CIAF.

I find a strongly significant and negative relationship between living in an urban area and both the probability of ARI and CIAF. There is a strongly significant and negative relationship between altitude and the probability of ARI and a positive relationship between altitude and the probability of CIAF. I find a strongly significant and negative relationship between the wealth quintiles, with exception to the middle quintile, and the probability of CIAF. There is a weakly significant and negative relationship between the household's head age and the probability of CIAF. There is a significantly positive relationship between the household size and the probability of ARI, and a weakly significant and positive relationship between the household size and CIAF. Cooking in a separate building, compared to cooking indoors, is strongly significant and negatively correlated with the probability of ARI.

### 5.1.3 Results From Ordinary Least Squares (OLS) Regressions for WHZ

Results from three OLS regressions for WHZ are presented in Table 20. Following the same format as previous regressions, results are presented in three columns, where model 7A contains child-level control variables, Model 8A adds mother-level control variables and Model 9A adds household-level control variables. In these regressions, ARI enters as an explanatory variable.

Looking at the child characteristics regression (Model 6A), I find a strongly significant and negative relationship between ARI and a child's WHZ. There is also a significant and negative relationship between the use of firewood and WHZ. Child's age is strongly significant and positively related with WHZ. There is a significant and negative relationship between the duration of breastfeeding and WHZ. There is a strongly significant and negative relationship between diarrhea and WHZ.

Controlling for mother factors (Model 7A), ARI remains strongly significant and negatively correlated with WHZ. Child's age remains strongly significant and positively related with WHZ. Duration of breastfeeding and diarrhea remains strongly significant and negatively correlated with WHZ. I find a strongly significant and positive relationship between mother's education and WHZ.

Additionally controlling for household factors (Model 8A), I find ARI to remain strongly significant and negatively correlated with WHZ. However, I do not find a significant result for the use of firewood. The child's age persistently remains strongly significant and positively related with WHZ. Both duration of breastfeeding and diarrhea remain strongly significant and negatively associated with WHZ. There is a weakly significant and positive relationship between wealth quintiles and WHZ. Sanitation is significant and positively related with WHZ.

### 5.1.4 Further Analysis of the Determinants of Health and Nutrition Outcome

The results presented in tables 18-20 show that the age of a child plays a significant role in explaining his or her health and malnutrition status. This relationship is further explored and the results are presented in Table 21. Observations were divided into three age cohorts; 0 to 12 months, 12 to 18 months and 18 to 60 months. There are 1100, 487 and 2876 observations in the sub-samples, respectively. Bivariate probit regressions similar to the baseline regressions, models (1A and 1B) are analyzed for each sub-sample of children.

For the first group, age 0 to 12 months, I find a strongly significant and positive relationship between the age of a child and both the probability of ARI and stunting. For the second cohort, age 12 to 18 months, the relationship between age and the probability of ARI is strongly significant and negative, whereas the relationship between age and the probability of stunting is weakly significant and positive. For the third cohort, age 18 to 60 months, the relationship between age and the probability of ARI is strongly significant and negative. Similarly, the relationship between age and stunting is strongly significant and negative.

To further illustrate the influence of a child's age on the health and nutrition outcome, the predicted probabilities of both ARI and stunting at each month were calculated from models (10, 11 and 12). Also, the predicted probabilities of both ARI and stunting at each month were calculated from model 13, which is presented in Table 22. Model 13 are bivariate probit regressions including a quadratic term for age. These predicted probabilities are presented in figures 27 and 28. In Figure 27, for the sub-sample model predictions, we see an increase in the probability of ARI between ages 0 and 12 months and a decrease afterwards. However, for the full sample predictions with the quadratic age term, we observe a downward trend beginning at 25 months. Similarly, in Figure 28, for the sub-sample model predictions, we see an increase in the probability of stunting between ages 0 and 18 months and a decrease afterwards. However, for the full sample predictions with the quadratic age term, the downward trend is observed to begin at 36 months.

## 5.2 Discussion

Looking at the results from the bivariate probit regressions for firewood (models 1, 2, 4 and 5) and cooking setting, we find support for the smoke exposure hypothesis. The positive relationship we find between the use of firewood and the probability of ARI is consistent with Mishra's (2003) finding that exposure to smoke from biomass combustion increases the risk of ARI. There are three possible explanations for the observed positive relationship between the use of firewood and the probability of malnutrition. First, access to firewood determines the frequency and quantity of food cooked. Since firewood is the major source of cooking energy, households that have limited access to fuel are likely to cook less and eat less, reducing the nutrient intake of children. Second, extensive ill health could be associated with stunting and children in household's that use firewood are more at risk of illness and diseases such as ARI. Third, both ARI and fuel use are correlated with poverty. To some extent, all three explanations probably apply. The positive relationship observed between the use of firewood and the probability of CIAF is interesting. Recall from Chapter 3 that CIAF is a combination of the various forms of malnutrition. So the results from models (4B and 5B) suggests that the use of firewood is correlated with either the probability of stunting or wasting or underweight or the combination. Interestingly, the use of firewood becomes insignificant for ARI, stunting and CIAF after controlling for household factors. This likely reflects the confounding association between the choice of fuel and household factors such as location and wealth. Similarly, the use of firewood is no longer significant for WHZ after controlling for mother factors. This likely reflects the confounding association between the use of firewood and mother characteristics such as education.

The strongly significant and negative relationship between cooking in a separate building, compared to cooking indoors, and the probability of ARI is consistent with expectations. This further supports the exposure hypothesis since cooking in a separate building likely reduces a child's exposure to harmful gases.

Our hypothesis on the influence of a child's age is supported by the results from all models. A possible explanation for the observed negative relationship between child's age and the probability of ARI, is that older children spend less time with their mother, who mainly does the cooking, and are therefore less frequently exposed to smoke from firewood. This further supports the exposure hypothesis. The positive relationship observed between the age of the child and probability of stunting is consistent with Kikafunda et al (1998) who report that the incidence of stunting appears to be higher among older children. Another possible explanation for the observed relationship between child's age and WHZ is that as children get older they become less prone to illnesses and diseases thereby decreasing the chances for weight loss. Also, older children may consume a more diversified diet, which could improve their nutrition intake and status.

Decomposing observations into sub-samples allows for an in-depth analysis of the influence of a child's age. The results from models (10, 11 and 12A) suggest that an increase in child's age is associated with a decrease in the probability of ARI and an increase in the probability of stunting. This is consistent with the results in models (1A and 1B). However the results from Model 12B suggest otherwise, that beginning from 18 months, an increase in child's age is associated with a decrease in the probability of stunting. Similarly, the results in figures 27 and 28 present an interesting contrast in the turning points.

There are possible explanations for the observed relationship between the sex of a child (male) and malnutrition outcome (models 1B, 2B, 3B, 4B, 5B and 6B). First, girls may spend more time with the mother doing the cooking thereby being more exposed to harmful gases. Second, the economic perception of male children, as farm labor assets, permits them to be given preferential treatment in terms of the type and quantity of food they receive. Similarly, preferential treatment of boys may be reinforced by cultural beliefs, thereby affording them to be better nourished than female children.

There is support for the experience hypothesis in the results (models 3B, 5B, and 6B). The negative relationship observed between a mother's age and the probability of malnutrition suggests that households with older mothers are less likely to have undernourished children. A possible explanation for this is that experience gained upon maturity allows for the older mother to make better household decisions. Likewise, older mothers are more likely to be connected to resources such as social and religious groups that may exposes them to information on nutrition. The weakly significant and negative relationship observed between the age of the head of household and the probability of CIAF further supports this experience hypothesis.

The positive influence of education on child nutrition outcome is supported by the results (models 2B, 3B, 5B, 6B, 8A and 9A). This is consistent with UNICEF's (1998) suggestion that education empowers women and helps improve their nutrition as well as their children's nutrition. Another possible explanation is that educated mothers are more inclined to the use of higher quality biomass hereby reducing the likelihood of their children's exposure to health hazard gases.

Living in an urban area is observed to be beneficial to health and nutrition outcome (based on models 3A, 3B, 6A, and 6B). A potential explanation for this is that people in urban areas have better access to higher quality cooking and heating fuels, health care and proper nutrition. Similarly, the negative relationship observed between altitude and the probability of ARI could be explained as household's located in higher altitudes have better access to cleaner fuels hereby limiting the exposure to harmful gases.[12]

The results (models 3B, 6B, and 9A) suggest that rates of malnutrition differ across wealth quintiles. This is consistent with expectations, as poverty is known to be an underlying cause of malnutrition. It is expected that the children of wealthier people benefit in multiple ways. These benefits include better quantity and quality of food, better health services and better education which in turn translates into better nutrition status.

I find support for the food and fuel demand hypothesis (based on models 3A, 3B, 6A, and 6B). The results confirm Jagger and Shively's (2014) findings that an increase in family size is associated with an increase in the likelihood of ARI. This may result from the increase in fuel consumption due to needs. Similarly, an increase in food demand that is not accompanied by an increase in income will most likely translate into a shortage of

[12] Our data suggests no strong correlation between altitude and wealth

food. Recall from Figure 1 that lack of food intake and infectious diseases are direct determinants of health and nutrition status.

The strongly significant and negative relationship observed between ARI and a child's WHZ is consistent with expectations (based on models 7A, 8A and 9A). There are two possible explanations for this: first, a child who is suffering from illnesses and diseases, such as ARI, is more likely to suffer from lack of appetite thus limiting food intake; second, the body channels extra nutrients into combating the infection thereby resulting in a loss of weight. These explanations are supported by the negative relationship observed between diarrhea and WHZ. The diarrhea result is also consistent with Guerrant et al. (1992) who reported a significant moderate weight loss with diarrheal illnesses. Similarly, the positive relationship observed between sanitation and WHZ is consistent with expectation as improved sanitation limits the spread of illnesses such as diarrhea and ARI.

Although the several effects have been considered separately, we cannot reject the hypothesis of a synergistic effect. For instance, one would expect, a priori, a household that resides in an urban area to be better educated and wealthier than a household that resides in a rural area. This expectation is based on the urban household's better access to available infrastructure. Similarly, there may be a synergistic effect between ARI and WHZ, as disease and illness may lead to an immediate loss of weight. Also, there could be a synergistic effect between ARI and stunting. Disentangling these complex connections, however, is difficult with the available data.

# CHAPTER 6. CONCLUSIONS, IMPLICATIONS AND LIMITATIONS

This thesis sought to explain the relationship between a household's choice of fuel and the health and nutrition outcomes of children below the age of 5 in Uganda. Nine primary hypotheses were tested. The findings provide insights to the underlying causes of poverty and underdevelopment. The results also provide insight into the policies and programs that might be relevant for addressing the rural and urban divide in malnutrition in developing countries.

## 6.1 Conclusion Addressing Hypotheses

For the bivariate probit regressions for the prevalence of ARI and stunting, the tetrachoric correlation obtained after controlling for household characteristics suggests a correlation between the reported symptoms of ARI and the probability of stunting in children below age 5. Controlling for only child and mother characteristics, the use of firewood appears to be positively correlated with both the probability of ARI and stunting. However, this is explained by household factors such as urban and wealth. Also, cooking in a separate building is negatively correlated with the probability of ARI. Possible explanations for the firewood and cooking setting results are; access to firewood may determine availability of cooked food; extensive ill health, associated with fuel use, could be associated with stunting; poverty is correlated with both ARI and fuel use. Location plays a role, as living in urban area is found to be negatively correlated with both the probability of ARI and stunting. A possible explanation for this is that households that reside in urban areas are more likely to have better access to higher quality fuels, health care and proper nutrition. The rate of malnutrition differs across wealth quintiles. This reflects that economic status is of importance in determining a child's nutrition. Family size is positively correlated with both the probability of ARI and stunting. This could be as a result of the increase in the use of firewood and the shortage in food supply posed by increased demand for food. Child's age is consistently negatively correlated with the probability of ARI and positively correlated with the probability of stunting. Explanations for this include the possibility that older children are less exposed to domestic health hazard gases because they tend to spend less time with their mothers while cooking, that children become less prone to illness and diseases as they grow older, and that older children consume more diversified diets. Being a male child is negatively correlated with the probability of stunting, suggesting preferential treatment of male children, perhaps for cultural and economic reasons. The duration of breastfeeding is negatively correlated with the probability of stunting. Surprisingly, receiving measles vaccination is positively correlated with the probability of stunting. I find that a mother's education level is negatively correlated with the probability of stunting. This suggests that educated mothers are more likely to be aware of the importance of proper nutrition and are more likely to afford it for their children. Altitude is negatively correlated with both the probability of ARI and stunting.

For the bivariate probit regressions for the prevalence of ARI and CIAF, the tetrachoric correlation obtained suggest a correlation between the reported symptoms of ARI and the probability of CIAF in children below age 5. Again, controlling for only child and mother characteristics, the use of firewood appears to be positively correlated with both the probability of ARI and CIAF. However, this is also explained by household factors. Cooking in a separate building is negatively correlated with the probability of ARI. Living in urban area is negatively correlated with both the probability of ARI and CIAF. Wealth quintile is negatively correlated with the probability of CIAF. Family size is positively correlated with both the probability of ARI and CIAF. Child's age is negatively correlated with the probability of ARI and positively correlated with the probability of CIAF, after controlling for mother's characteristics. Being a male child is negatively correlated with the probability of CIAF. The duration of breastfeeding is negatively correlated with the probability of CIAF. Mother's education level is negatively correlated with the probability of CIAF. Altitude is negatively correlated with the probability of ARI and positively correlated with the probability of CIAF.

For the multivariate linear regression addressing the WHZ, I find that children with ARI symptoms have lower WHZ. Possible explanations for this are that diseases and illness are associated with a lack of appetite, and/or that the body diverts all available nutrients into combating the illness and disease. Controlling for only child characteristics, I find that children in households that use firewood, have lower WHZ. Similarly, WHZ differs across wealth quintiles. Child's age is positively correlated with WHZ and the duration of breastfeeding is negatively correlated with WHZ. Mother's education level is positively correlated with WHZ. I find that children who had experienced diarrhea have lower WHZ. Improved sanitation is positively correlated with WHZ.

## 6.2 Implications

The findings in this thesis suggest important implications for programs and policy interventions. First, firewood is the major source of fuel in developing countries. An intervention promoting the use of modern fuels could be an effective mechanism to reduce exposure to harmful gases. However, in a situation where households are unable to afford modern fuels, a public program creating awareness of the health risks associated with the combustion of lower quality biomass and the benefits of cooking in a separate building, may be most appropriate.

Second, findings suggest that family size is a key determinant for health and nutritional outcome. If family size is associated with the demand for firewood, public campaigns on family planning could be effective in tackling the issue of indoor air pollution through addressing the issue of firewood demand.

Third, the age of the child is correlated with health and nutrition outcomes. Programs targeted at educating mothers on careful cooking practices, particularly child care while cooking, could be effective at decreasing child exposure to harmful gases.

Fourth, findings also suggest that programs and policies targeting rural areas will be most effective at addressing health and nutrition issues. This is due to the higher concentration of firewood users as well as larger families located in rural areas.

## 6.3 Limitation and Further Research

There are limitations to this analysis which should be considered when interpreting results. First, clinical measurement such as urinary cotinine is a more accurate technique of estimating smoke exposure. However, proxies such as type of fuel and family size were used to estimate smoke exposure thereby introducing a measure of inaccuracy. Second, there is limited variation in the fuel data. A majority of households in the DHS reported the use of firewood or charcoal, thereby presenting a constraint to the analysis of the influence of other types of fuel. Third, information on the actual quantity of wood fuel used was not collected. This prevents us from directly quantifying smoke exposure. Fourth, information on the proximity to forest was not collected, so we are unable to distinguish the quality of fuel by the source. Fifth, there was no information on the duration of cooking. This could have aided in accurately measuring smoke exposure. Sixth, information on ARI symptoms are based upon the information reported by the mother. If mothers are unable to recall incidence, this may lead to false reports and associations. Seventh, several interventions have advocated for the use of modern stoves. Unfortunately, there was no information in the DHS dataset to enable us study the effectiveness of such programs.

Further studies should attempt to include information on the proximity to forest, quantity of fuel used and duration of cooking. Also, further research should analyze the benefits and costs of the several policy interventions in this area.

Table 1. Hypothesized Determinants of ARI and Malnutrition and Expected Relationship

**HYPOTHESES**

| | Variables | ARI | HAZ <-2 | WHZ<-2 | CIAF[13] |
|---|---|---|---|---|---|
| Child Characteristics | Child Age | | + | + | + |
| | Child Sex (1 if male, 0 otherwise) | | | - | - |
| | Breastfeeding Duration | | - | - | - |
| | Vitamin A immunization | | - | - | - |
| | Diarrhea | | + | + | + |
| | Measles | | + | + | + |
| Mother Characteristics | Mother Age | - | - | - | - |
| | Primary Education (mother) | + | + | + | + |
| | Secondary Education(mother) | - | - | - | - |
| | Higher Education (mother) | - | - | - | - |
| | Smoking Cigarette (mother) | + | | | |
| | Maternal Health Status (BMI) | | - | - | - |
| Household Characteristics | Urban (1 if Urban, 0 otherwise) | - | - | - | - |
| | Region (10) | +/- | +/- | +/- | +/- |
| | Wealth Quintile 1 (Poorest) | + | + | + | + |
| | Wealth Quintile 2 (Poorer) | + | + | + | + |
| | Wealth Quintile 3 (Middle) | - | - | - | - |
| | Wealth Quintile 4 (Richer) | - | - | - | - |
| | Wealth Quintile 5 (Richest) | - | - | - | - |
| | Fuel Portfolio | + | + | + | + |
| | Household Size | + | + | + | + |
| | Head of Household Sex (1 if female, 0 otherwise) | + | + | + | + |
| | Female Household Members | + | + | + | + |
| | Head of Household Age | - | - | - | - |
| | Water Source (1 if improved, 0 otherwise) | | + | + | + |
| | Sanitation ( 1 if improved, 0 otherwise) | | - | - | - |
| | Cooking Method (1 if stove, 0 otherwise) | - | | | |
| | Outdoor Cooking | - | | | |
| | In House Cooking | + | | | |
| | Separate Building Cooking | - | | | |
| | Chimney | - | | | |

[13] Acute Respiratory Infection (ARI); Stunting (HAZ<-2); Wasting (WAZ<-2); Composite Indexes of Anthropometric Failure (CIAF)

Table 2. Proportions of Composite Indexes of Anthropometric Failure (CIAF)

| Groups | Description | Proportion | | Std. Err. | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| A | No failure | 0 | .40 | 0.007 | 0.38 | 0.41 |
| | | 1 | .60 | 0.007 | 0.59 | 0.62 |
| B | Wasting only | 0 | .98 | 0.002 | 0.98 | 0.99 |
| | | 1 | .02 | 0.002 | 0.01 | 0.02 |
| C | Wasting & underweight | 0 | .98 | 0.002 | 0.98 | 0.98 |
| | | 1 | .02 | 0.002 | 0.02 | 0.02 |
| D | Wasting, stunting & underweight | 0 | .98 | 0.002 | 0.98 | 0.98 |
| | | 1 | .02 | 0.002 | 0.02 | 0.02 |
| E | Stunting & underweight | 0 | .90 | 0.005 | 0.89 | 0.91 |
| | | 1 | .10 | 0.005 | 0.09 | 0.11 |
| F | Stunting only | 0 | .77 | 0.006 | 0.76 | 0.79 |
| | | 1 | .23 | 0.006 | 0.21 | 0.24 |
| Y | Underweight only | 0 | .99 | 0.001 | 0.99 | 0.99 |
| | | 1 | .01 | 0.001 | 0.01 | 0.01 |

Note: Classifications based on Nandy et al., 2005. Source: UDHS. n= 4463.

Table 3. Summary of Explanatory Variables

| Category | Variable name | Variable Label | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|
| | urban | 1=urban, 0=rural | 0.16 | 0.362 | 0 | 1 |
| | district | district | 257.46 | 109.150 | 101 | 419 |
| | region | region | 5.71 | 2.753 | 1 | 10 |
| **Child** | sex | sex of child, 1=male 2=female | 1.50 | 0.500 | 1 | 2 |
| | agemon | child age in months | 27.69 | 17.089 | 0 | 59 |
| | ARI1 | ARI symptoms (cough + fever), 1=ARI1, 0=not | 0.29 | 0.453 | 0 | 1 |
| | ARI2 | ARI1*short, rapid breaths. 1=ARI2, 0=not | 0.16 | 0.362 | 0 | 1 |
| | stunting | haz <-2, 1=stunted, 0=not | 0.35 | 0.477 | 0 | 1 |
| | wasting | whz <-2, 1=wasted, 0=not | 0.06 | 0.235 | 0 | 1 |
| | underweight | waz <-2, 1=underweight, 0=not | 0.15 | 0.360 | 0 | 1 |
| | Group A | 1=no anthropometric Failure, 0=Failure | 0.60 | 0.489 | 0 | 1 |
| | Group B | 1=Wasting Only, 0=not | 0.02 | 0.134 | 0 | 1 |
| | Group C | 1= Wasting + Underweight, 0=not | 0.02 | 0.140 | 0 | 1 |
| | Group D | 1= Wasting + Stunting + Undwerweight, 0=not | 0.02 | 0.141 | 0 | 1 |
| | Group E | 1=Stunting + Underweight, 0=not | 0.10 | 0.304 | 0 | 1 |
| | Group F | 1=Stunting Only, 0=not | 0.23 | 0.418 | 0 | 1 |
| | Group Y | 1=Underweight Only, 0=not | 0.01 | 0.099 | 0 | 1 |

Table 3 continued.

| | | | | | | |
|---|---|---|---|---|---|---|
| | CIAF | 1=Anthropometric failure, 0=not | 0.40 | 0.489 | 0 | 1 |
| | bcg | 1=received bcg, 0=not | 0.90 | 0.299 | 0 | 1 |
| | dpt1 | 1=received dpt 1, 0=not | 0.61 | 0.487 | 0 | 1 |
| | polio1 | 1=received polio 1, 0=not | 0.88 | 0.329 | 0 | 1 |
| | dpt2 | 1= received dpt 2, 0=not | 0.54 | 0.499 | 0 | 1 |
| | polio2 | 1=received polio 2, 0=not | 0.76 | 0.424 | 0 | 1 |
| | dpt3 | 1=received dpt 3, 0=not | 0.42 | 0.494 | 0 | 1 |
| | polio3 | 1=received polio 3, 0=not | 0.54 | 0.498 | 0 | 1 |
| | measles | 1=received measles, 0=not | 0.63 | 0.482 | 0 | 1 |
| | vacc | 1=ever had vaccination, 0=not | 0.37 | 0.484 | 0 | 1 |
| | diarrhea | 1=had diarrhea in last two weeks, 0=not | 0.26 | 0.439 | 0 | 1 |
| | ort | 1=given oral rehydration, 0=not | 0.12 | 0.321 | 0 | |
| | vitamin_a | 1=vitamin a in last 6 months, 0=not | 0.40 | 0.491 | 0 | 1 |
| | anelevel | anemia level | 3.43 | 1.919 | 1 | 9 |
| **Mother** | | | | | | |
| | placeofdiatreat | place first sought treatment for diarrhea | 18.27 | 8.982 | 11 | 99 |
| | respondage | current age - respondent | 28.89 | 6.647 | 15 | 49 |
| | priorresyrs | years lived in place of res. | 24.45 | 35.625 | 0 | 96 |
| | typeofpriorres | type of place of previous res. | 2.83 | 0.605 | 1 | 9 |

Table 3 continued.

| | | | | | | |
|---|---|---|---|---|---|---|
| | momworks | worked in last 12 months | 1.71 | 0.760 | 0 | 9 |
| | religion | religion | 3.48 | 12.157 | 1 | 99 |
| | eduinsingleyrs | education in single years | 4.60 | 3.798 | 0 | 19 |
| | n5andunder | number of children 5 and under | 2.11 | 0.885 | 0 | 6 |
| | ageofHH | age of household head | 36.97 | 11.687 | 17 | 94 |
| | literacy | iteracy | 1.00 | 1.013 | 0 | 9 |
| | sayonhealth | final say on own health care | 2.56 | 1.247 | 1 | 9 |
| | durofbreastf | duration of breastfeeding | 70.64 | 35.418 | 0 | 99 |
| | typeofearns | type of earnings for work | 1.25 | 1.011 | 0 | 9 |
| | decisiontospend | who decides how to spend money | 1.84 | 1.245 | 1 | 9 |
| | smokescig | smokes cigarettes | 0.01 | 0.157 | 0 | 9 |
| | cmarsta | current marital status | 1.53 | 1.034 | 0 | 5 |
| | huslivinhous | husband lives in house | 1.18 | 0.587 | 1 | 9 |
| | nofotherwive | number of other wives | 2.93 | 15.652 | 0 | 99 |
| | earnsmore | earns more than partner | 2.27 | 1.293 | 1 | 9 |
| **Household** | | | | | | |
| | fhoh | 1=female headed, 0=male headed | 0.24 | 0.426 | 0 | 1 |
| | nofHHmem | number of household members | 6.61 | 2.729 | 2 | 22 |
| | dep_ratio | household total dependency ratio | 1.81 | 1.112 | 0.14 | 9 |

Table 3 continued.

| | | | | | |
|---|---|---|---|---|---|
| toiletshared | toilet facilities shared | 0.68 | 1.260 | 0 | 9 |
| sourceofdwater | source of drinking water | 28.46 | 11.382 | 11 | 96 |
| time2water back | time to get to water source, get water and come back | 121.52 | 245.747 | 1 | 998 |
| electricity | has electricity | 0.10 | 0.414 | 0 | 9 |
| mfloormater | main floor material | 16.52 | 10.073 | 11 | 96 |
| mwallmater | main wall material | 25.58 | 9.479 | 11 | 96 |
| mroofmater | main roof material | 17.52 | 7.861 | 11 | 96 |
| rmsforsleep | rooms used for sleeping | 2.29 | 6.242 | 0 | 99 |
| charcoal | 1=charcoal, 0=not | 0.17 | 0.374 | 0 | 1 |
| firewood | 1=firewood, 0=not | 0.82 | 0.380 | 0 | 1 |
| stoveoropenfire | food cooked on stove or open fire | 1.13 | 0.364 | 1 | 9 |
| chimneyhood | household has a chimney, hood or neither | 0.08 | 0.682 | 0 | 9 |
| placeofcook /outdoors | food cooked in the house/ in separate building /outdoors | 2.17 | 0.650 | 1 | 9 |
| seperatekitchen | household has separate room used as kitchen | 0.45 | 0.962 | 0 | 9 |
| wealthindex | wealth index | 2.85 | 1.438 | 1 | 5 |
| wealthindexfact | wealth index factor score (5 decimals) | 13203.86 | 88061 | -13654 | 40954 |

Source: UDHS (2006/2011).

Table 4. Bivariate Tabulation of Fuel Wood and Location (Frequency and Column percentage)

| | | | 0=rural | 1=urban | |
|---|---|---|---|---|---|
| Firewood | | | 0 | 1 | Total |
| | Other | 0 | 243 | 540 | 783 |
| | | | (6.45) | (77.9) | (17.54) |
| | Firewood | 1 | 3,527 | 153 | 3,680 |
| | | | (93.55) | (22.08) | (82.46) |
| Total | | | 3,770 | 693 | 4,463 |
| | | | (100) | (100) | (100) |

Pearson chi2(1) = 2.1e+03 Pr = 0.000

Kendall's tau-b = -0.6806

Source: UDHS (2006/2011).

Table 5. Bivariate Tabulation of Charcoal and Location (Frequency and Column percentage)

| | | | 1=urban | 0=rural | |
|---|---|---|---|---|---|
| Charcoal | | | 0 | 1 | Total |
| | Other | 0 | 3,549 | 164 | 3,713 |
| | | | (94.14) | (23.67) | (83.2) |
| | Charcoal | 1 | 221 | 529 | 750 |
| | | | (5.86) | (76.33) | (16.8) |
| Total | | | 3,770 | 693 | 4,463 |
| | | | (100) | (100) | (100) |

Pearson chi2(1) = 2.1e+03 Pr = 0.000

Kendall's tau-b = 0.6826

Source: UDHS (2006/2011).

Table 6. Bivariate Tabulation of ARI and Location (Frequency and Column percentage)[14]

| | | 1=urban | 0=rural | |
|---|---|---|---|---|
| ARI symptoms | | 0 | 1 | Total |
| | 0 | 2,624 | 549 | 3,173 |
| | | (69.6) | (79.22) | (71.1) |
| | 1 | 1,146 | 144 | 1,290 |
| | | (30.4) | (20.78) | (28.9) |
| Total | | 3,770 | 693 | 4,463 |
| | | (100) | (100) | (100) |

Pearson Chi2(1)= 26.3555 Pr= 0.000

Kendall's tau-b = -0.0768

Source: UDHS (2006/2011).

Table 7. Bivariate Tabulation of CIAF and Location (Frequency and Column percentage)

| | | 1=urban | 0=rural | |
|---|---|---|---|---|
| CIAF | | 0 | 1 | Total |
| | 0 | 2,170 | 519 | 2,689 |
| | | (57.56) | (74.89) | (60.25) |
| | 1 | 1,600 | 174 | 1,774 |
| | | (42.44) | (25.11) | (39.75) |
| Total | | 3,770 | 693 | 4,463 |
| | | (100) | (100) | (100) |

Pearson chi2(1) = 73.4276 Pr = 0.000

Kendall's tau-b = -0.1283

Source: UDHS (2006/2011).

[14] Acute Respiratory Infection (ARI); Composite Indexes of Anthropometric Failure (CIAF)

Table 8. Bivariate Tabulation of Stunting and Location (Frequency and Column percentage)

| | | 1=urban | 0=rural | |
|---|---|---|---|---|
| haz<-2 | | 0 | 1 | Total |
| | 0 | 2,353 | 551 | 2,904 |
| | | (62.41) | (79.51) | (65.07) |
| | 1 | 1,417 | 142 | 1,559 |
| | | (37.59) | (20.49) | (34.93) |
| Total | | 3,770 | 693 | 4,463 |
| | | (100) | (100) | (100) |

Pearson chi2(1) = 75.2708 Pr = 0.000

Kendall's tau-b = -0.1299

Source: UDHS (2006/2011).

Table 9. Bivariate Tabulation of Wasting and Location (Frequency and Column percentage)

| | | 1=urban | 0=rural | |
|---|---|---|---|---|
| whz<-2 | | 0 | 1 | Total |
| | 0 | 3,544 | 657 | 4,201 |
| | | (94.01) | (94.81) | (94.13) |
| | 1 | 226 | 36 | 262 |
| | | (5.99) | (5.19) | (5.87) |
| Total | | 3,770 | 693 | 4,463 |
| | | (100) | (100) | (100) |

Pearson chi2(1) = 0.6778 Pr =0.410

Kendall's tau-b = -0.0123

Source: UDHS (2006/2011).

Table 10. Bivariate Tabulation of Underweight and Location (Frequency and Column percentage)

| | | 1=urban | 0=rural | |
|---|---|---|---|---|
| waz<-2 | | 0 | 1 | Total |
| | 0 | 3,141 | 639 | 3,780 |
| | | (83.32) | (92.21) | (84.7) |
| | 1 | 629 | 54 | 683 |
| | | (16.68) | (7.79) | (15.3) |
| Total | | 3,770 | 693 | 4,463 |
| | | (100) | (100) | (100) |

Pearson chi2(1) = 35.7110 Pr = 0.000

Kendall's tau-b = -0.0895

Source: UDHS (2006/2011).

Table 11. Bivariate Tabulation of Firewood and ARI (Frequency and Column percentage)[15]

| | | 0=No ARI | 1=ARI | |
|---|---|---|---|---|
| Fuel= wood | | 0 | 1 | Total |
| | 0 | 607 | 176 | 783 |
| | | (19.13) | (13.64) | (17.54) |
| | 1 | 2,566 | 1,114 | 3,680 |
| | | (80.87) | (86.36) | (82.46) |
| Total | | 3,173 | 1,290 | 4,463 |
| | | (100) | (100) | (100) |

Pearson chi2(1) = 19.0857 Pr = 0.000

Kendall's tau-b = 0.0654

Source: UDHS (2006/2011).

[15] Acute Respiratory Infection (ARI)

Table 12. Bivariate Tabulation of Charcoal and ARI (Frequency and Column percentage)[16]

| | | 0=No ARI | 1=ARI | |
|---|---|---|---|---|
| Fuel=charcoal | | 0 | 1 | Total |
| | 0 | 2,591 | 1,122 | 3,713 |
| | | (81.66) | (86.98) | (83.2) |
| | 1 | 582 | 168 | 750 |
| | | (18.34) | (13.02) | (16.8) |
| Total | | 3,173 | 1,290 | 4,463 |
| | | (100) | (100) | (100) |

Pearson chi2(1) = 18.5593 Pr = 0.000

Kendall's tau-b = -0.0645

Source: UDHS (2006/2011).

Table 13. Bivariate Tabulation of Location and ARI (Frequency and Column percentage)

| | | 0=No ARI | 1=ARI | |
|---|---|---|---|---|
| 1=urban, 0=rural | | 0 | 1 | Total |
| | 0 | 2,624 | 1,146 | 3,770 |
| | | (82.7) | (88.84) | (84.47) |
| | 1 | 549 | 144 | 693 |
| | | (17.3) | (11.16) | (15.53) |
| Total | | 3,173 | 1,290 | 4,463 |
| | | (100) | (100) | (100) |

Pearson chi2(1) = 26.3555 Pr = 0.000

Kendall's tau-b = -0.0768

Source: UDHS (2006/2011).

[16] Acute Respiratory Infection (ARI)

Table 14. Bivariate Tabulation of CIAF and ARI (Frequency and Column percentage)[17]

| | | 0=No ARI | 1=ARI | |
|---|---|---|---|---|
| CIAF | | 0 | 1 | Total |
| | 0 | 1,940 | 749 | 2,689 |
| | | (61.14) | (58.06) | (60.25) |
| | 1 | 1,233 | 541 | 1,774 |
| | | (38.86) | (41.94) | (39.75) |
| Total | | 3,173 | 1,290 | 4,463 |
| | | (100) | (100) | (100) |

Pearson chi2(1) = 3.6301 Pr = 0.057

Kendall's tau-b = 0.0285

Source: UDHS (2006/2011).

Table 15. Bivariate Tabulation of Stunting and ARI (Frequency and Column percentage)

| | | 0=No ARI | 1=ARI | |
|---|---|---|---|---|
| haz<-2 | | 0 | 1 | Total |
| | 0 | 2,086 | 818 | 2,904 |
| | | (65.74) | (63.41) | (65.07) |
| | 1 | 1,087 | 472 | 1,559 |
| | | (34.26) | (36.59) | (34.93) |
| Total | | 3,173 | 1,290 | 4,463 |
| | | (100) | (100) | (100) |

Pearson chi2(1) = 2.1931 Pr = 0.139

Kendall's tau-b = 0.0222

Source: UDHS (2006/2011).

[17] Acute Respiratory Infection (ARI); Composite Indexes of Anthropometric Failure (CIAF)

Table 16. Bivariate Tabulation of Wasting and ARI (Frequency and Column percentage)[18]

| | | 0=No ARI | 1=ARI | |
|---|---|---|---|---|
| whz<-2 | | 0 | 1 | Total |
| | 0 | 3,001 | 1,200 | 4,201 |
| | | (94.58) | (93.02) | (94.13) |
| | 1 | 172 | 90 | 262 |
| | | (5.42) | (6.98) | (5.87) |
| Total | | 3,173 | 1,290 | 4,463 |
| | | (100) | (100) | (100) |

Pearson chi2(1) = 4.0184 Pr = 0.045

Kendall's tau-b = 0.0300

Source: UDHS (2006/2011).

Table 17. Bivariate Tabulation of Underweight and ARI (Frequency and Column percentage)

| | | 0=No ARI | 1=ARI | |
|---|---|---|---|---|
| waz<-2 | | 0 | 1 | Total |
| | 0 | 2,734 | 1,046 | 3,780 |
| | | (86.16) | (81.09) | (84.7) |
| | 1 | 439 | 244 | 683 |
| | | (13.84) | (18.91) | (15.3) |
| Total | | 3,173 | 1,290 | 4,463 |
| | | (100) | (100) | (100) |

Pearson chi2(1) = 18.2546 Pr = 0.045

Kendall's tau-b = 0.0640

Source: UDHS (2006/2011).

[18] Acute Respiratory Infection (ARI)

Table 18. Seemingly Unrelated Bivariate Probit Regression Results for Prevalence of ARI and Stunting

| | ARI | | | Stunting | | |
|---|---|---|---|---|---|---|
| Variables | 1A: Child Characteristics | 2A: Mother Characteristics | 3A: Household Characteristics | 1B: Child Characteristics | 2B: Mother Characteristics | 3B: Household Characteristics |
| Firewood | 0.2522*** | 0.2230*** | 0.1003 | 0.4095*** | 0.2777*** | -0.0137 |
| | (0.0549) | (0.0596) | (0.0880) | (0.0547) | (0.0598) | (0.0883) |
| Child's Age in Months | -0.0039*** | -0.0038*** | -0.0042*** | 0.0065*** | 0.0072*** | 0.0071*** |
| | (0.0012) | (0.0012) | (0.0012) | (0.0014) | (0.0015) | (0.0015) |
| Sex (1 if male, 0 otherwise) | 0.0291 | 0.0278 | 0.0360 | -0.1729*** | -0.1811*** | -0.1841*** |
| | (0.0398) | (0.0399) | (0.0404) | (0.0391) | (0.0393) | (0.0397) |
| Duration of Breastfeeding | | | | -0.0019*** | -0.0017*** | -0.0017*** |
| | | | | (0.0006) | (0.0006) | (0.0006) |
| Measles Vaccination | | | | 0.1016** | 0.1236 | 0.1411*** |
| | | | | (0.0468) | (0.0471) | (0.0482) |
| Vitamin A | | | | -0.0136 | -0.0055 | 0.0066 |
| | | | | (0.0412) | (0.0415) | (0.0426) |
| Mothers Age | | -0.0019 | -0.0023 | | -0.0133 | -0.0144*** |
| | | (0.0031) | (0.0035) | | (0.0031) | (0.0034) |
| Mothers Education Level | | | | | | |
| 2. Primary | | 0.0435 | 0.0412 | | -0.1202** | -0.0965* |
| | | (0.0519) | (0.0571) | | (0.0500) | (0.0550) |
| 3. Secondary | | -0.0300 | -0.0178 | | -0.4046*** | -0.3154*** |
| | | (0.0744) | (0.0828) | | (0.0740) | (0.0822) |
| 4. Higher | | -0.1463 | -0.0800 | | -0.6810*** | -0.5393*** |
| | | (0.1269) | (0.1364) | | (0.1371) | (0.1462) |

Table 18 continued.

| | | | | |
|---|---|---|---|---|
| Mother Smokes Cigarette | 0.0829 | 0.0444 | | |
| | (0.1249) | (0.1257) | | |
| Mothers BMI | | | -0.0000 | -.0001 |
| | | | (0.0000) | (0.0000) |
| Urban | | -0.2142** | | -0.2707*** |
| | | (0.0910) | | (0.0916) |
| Altitude | | -0.0004*** | | 0.0003*** |
| | | (0.0001) | | (0.0001) |
| Wealth Quintiles | | | | |
| 2. Poorer | | -0.0876 | | -0.1807*** |
| | | (0.0647) | | (0.0640) |
| 3. Middle | | -0.0786 | | 0.0067 |
| | | (0.0719) | | (0.0703) |
| 4. Richer | | -0.0796 | | -0.1795** |
| | | (0.0774) | | (0.0773) |
| 5. Richest | | -0.1376 | | -0.3139*** |
| | | (0.0995) | | (0.1038) |
| Age (Head of Household) | | -0.0013 | | -0.0038* |
| | | (0.0020) | | (0.0020) |
| Household Size | | 0.0257** | | 0.0232** |
| | | (0.0110) | | (0.0110) |
| Female Headed Household | | 0.0288 | | 0.0759 |
| | | (0.0492) | | (0.0485) |
| Number of Women | | -0.0217 | | -0.0395 |
| | | (0.0351) | | (0.0351) |
| Cooking Setting | | | | |

Table 18 continued.

| | | | | | | |
|---|---|---|---|---|---|---|
| 2. Separate Building | | | -0.2164*** | | | -0.0533 |
| | | | (0.0709) | | | (0.0707) |
| 3. Outdoors | | | -0.0566 | | | 0.0305 |
| | | | (0.0716) | | | (0.0715) |
| Sanitation | | | | | | -0.0208 |
| | | | | | | (0.0587) |
| Water Source | | | | | | 0.0022 |
| | | | | | | (0.0480) |
| Constant | -0.7035*** | -0.6440*** | 0.0955 | -0.5837*** | 0.1230 | 0.2273 |
| | (0.0848) | (0.1344) | (0.2390) | (0.1042) | (0.1606) | (0.2516) |
| Region Effect | No | No | YES | No | No | YES |
| N | 4463 | 4463 | 4461 | | | |
| Log-likelihood | -5469.9877 | -5435.0612 | -5315.49 | | | |
| Corr(ARI, Stunting) | 0.0405 | 0.0354 | 0.0454* | | | |
| | (0.0259) | (0.0261) | (0.0266) | | | |
| $\chi^2$ for ρ(ARI, Stunting) | 2.434 | 1.837 | 2.912 | | | |

Note: Standard errors are presented in parentheses.
*,**,*** Statistically significant at the 10, 5 and 1% levels respectively.
Acute Respiratory Infection (ARI)
Source: UDHS (2006/2011)

Table 19. Seemingly Unrelated Bivariate Probit Regression Results for Prevalence of ARI and CIAF

| | ARI | | | CIAF | | |
|---|---|---|---|---|---|---|
| Variables | 4A: Child Characteristics | 5A: Mother Characteristics | 6A: Household Characteristics | 4B: Child Characteristics | 5B: Mother Characteristics | 6B: Household Characteristics |
| Firewood | 0.2522*** | 0.2231*** | 0.1004 | 0.3871*** | 0.2567*** | -0.0382 |
| | (0.0549) | (0.0596) | (0.0880) | (0.0528) | (0.0578) | (0.0856) |
| Child's Age in Months | -0.0039*** | -0.0038*** | -0.0042*** | 0.0020 | 0.0025* | 0.0023 |
| | (0.0012) | (0.0012) | (0.0012) | (0.0014) | (0.0014) | (0.0015) |
| Sex (1 if male, 0 otherwise) | 0.0291 | 0.0278 | 0.0360 | -0.1615*** | -0.1699*** | -0.1724*** |
| | (0.0398) | (0.0399) | (0.0404) | (0.0383) | (0.0385) | (0.0388) |
| Duration of Breastfeeding | | | | -0.0017*** | -0.0015** | -0.0016*** |
| | | | | (0.0006) | (0.0006) | (0.0006) |
| Measles Vaccination | | | | 0.0286 | 0.0493 | 0.0652 |
| | | | | (0.0459) | (0.0462) | (0.0472) |
| Vitamin A | | | | -0.0219 | -0.0157 | -0.0074 |
| | | | | (0.0404) | (0.0406) | (0.0417) |
| Mothers Age | | -0.0019 | -0.0023 | | -0.0123*** | -0.0130*** |
| | | (0.0031) | (0.0035) | | (0.0030) | (0.0033) |
| Mothers Education Level | | | | | | |
| 2. Primary | | 0.0436 | 0.0412 | | -0.1468*** | -0.1079** |
| | | (0.0519) | (0.0571) | | (0.0494) | (0.0542) |
| 3. Secondary | | -0.0298 | -0.0177 | | -0.4132*** | -0.3064*** |
| | | (0.0744) | (0.0827) | | (0.0720) | (0.0800) |
| 4. Higher | | -0.1458 | -0.0798 | | -0.6578*** | -0.4994*** |
| | | (0.1269) | (0.1364) | | (0.1291) | (0.1379) |

Table 19 continued.

| | | | | |
|---|---|---|---|---|
| Mother Smokes Cigarette | 0.0831 | 0.0449 | | |
| | (0.1250) | (0.1258) | | |
| Mothers BMI | | | -0.0000 | -.0000 |
| | | | (0.0000) | (0.0000) |
| Urban | | -0.2144** | | -0.2487*** |
| | | (0.0910) | | (0.0883) |
| Altitude | | -0.0004*** | | 0.0004*** |
| | | (0.0001) | | (0.0001) |
| Wealth Quintiles | | | | |
| 2. Poorer | | -0.0878 | | -0.1745*** |
| | | (0.0647) | | (0.0627) |
| 3. Middle | | -0.0788 | | -0.0313 |
| | | (0.0719) | | (0.0691) |
| 4. Richer | | -0.0798 | | -0.2344*** |
| | | (0.0774) | | (0.0759) |
| 5. Richest | | -0.1376 | | -0.3291*** |
| | | (0.0995) | | (0.1010) |
| Age (Head of Household) | | -0.0013 | | -0.0037* |
| | | (0.0020) | | (0.0019) |
| Household Size | | 0.0257** | | 0.0200* |
| | | (0.0110) | | (0.0107) |
| Female Headed Household | | 0.0284 | | 0.0468 |
| | | (0.0492) | | (0.0475) |
| Number of Women | | -0.0215 | | -0.0229 |
| | | (0.0351) | | (0.0340) |
| Cooking Setting | | | | |

Table 19 continued

| | | | | | | |
|---|---|---|---|---|---|---|
| 2. Separate Building | | | -0.2164*** | | | 0.0056 |
| | | | (0.0709) | | | (0.0692) |
| 3. Outdoors | | | -0.0566 | | | 0.0269 |
| | | | (0.0717) | | | (0.0701) |
| Sanitation | | | | | | -0.0250 |
| | | | | | | (0.0572) |
| Water Source | | | | | | -0.0259 |
| | | | | | | (0.0470) |
| Constant | -0.7037*** | -0.6441*** | 0.0953 | -0.2867*** | 0.3956** | 0.4788* |
| | (0.0848) | (0.1344) | (0.2390) | (0.1018) | (0.1568) | (0.2452) |
| Region Effect | No | No | YES | No | No | YES |
| N | 4463 | 4463 | 4461 | | | |
| Log-likelihood | -5615.0569 | -5581.5872 | -5461.8565 | | | |
| Corr(ARI, CIAF) | 0.0440* | 0.0391 | 0.0486* | | | |
| | (0.0254) | (0.0255) | (0.0260) | | | |
| $\chi^2$ for ρ(ARI, CIAF) | 2.996 | 2.348 | 3.487 | | | |

Note: Standard errors are presented in parentheses
*,**,*** Statistically significant at the 10, 5, and 1% levels respectively.
Acute Respiratory Infection (ARI); Composite Indexes of Anthropometric Failure (CIAF)
Source: UDHS (2006/2011)

Table 20. Multiple Linear Regression Results for WHZ

| Variables | 7A: Child Characteristics | 8A: Mother Characteristics | 9A: Household Characteristics |
|---|---|---|---|
| ARI | -0.1847*** | -0.1812*** | -0.1663*** |
| | (0.0420) | (0.0418) | (0.0420) |
| Firewood | -0.1246** | -0.0154 | 0.0451 |
| | (0.0493) | (0.0538) | (0.0791) |
| Child's Age in Months | 0.0069*** | 0.0071*** | 0.0078*** |
| | (0.0014) | (0.0014) | (0.0014) |
| Sex (1 if male, 0 otherwise) | -0.0265 | -0.0269 | -0.0269 |
| | (0.0369) | (0.0367) | (0.0364) |
| Duration of Breastfeeding | -0.0027*** | -0.0028*** | -0.0022*** |
| | (0.00s06) | (0.0006) | (0.0006) |
| Measles Vaccination | 0.0177 | 0.0144 | 0.0250 |
| | (0.0445) | (0.0443) | (0.0445) |
| Vitamin A | -0.0255 | -0.0251 | 0.0028 |
| | (0.0390) | (0.0388) | (0.0392) |
| Diarrhea | -0.1825*** | -0.1774*** | -0.1756*** |
| | (0.0442) | (0.0440) | (0.0439) |
| Mothers Age | | -0.0015 | -0.0038 |
| | | (0.0029) | (0.0031) |
| Mothers Education Level | | | |
| 2. Primary | | 0.2519*** | 0.1402*** |
| | | (0.0480) | (0.0518) |
| 3. Secondary | | 0.2681*** | 0.1244* |
| | | (0.0681) | (0.0747) |
| 4. Higher | | 0.3540*** | 0.1790 |
| | | (0.1120) | (0.1184) |
| Mothers BMI | | 0.0002*** | 0.0001*** |
| | | (0.0000) | (0.0000) |
| Urban | | | 0.0714 |
| | | | (0.0799) |
| Altitude | | | -0.0002* |
| | | | (0.0001) |
| Wealth Quintiles | | | |
| 2. Poorer | | | 0.1004* |
| | | | (0.0595) |

Table 20 continued.

| | | | |
|---|---|---|---|
| 3. Middle | | | 0.1204* |
| | | | (0.0660) |
| 4. Richer | | | 0.1254* |
| | | | (0.0716) |
| 5. Richest | | | 0.1198 |
| | | | (0.0939) |
| Age (Head of Household) | | | 0.0007 |
| | | | (0.0018) |
| Household Size | | | 0.0009 |
| | | | (0.0100) |
| Female Headed Household | | | -0.0355 |
| | | | (0.0445) |
| Number of Women | | | -0.0237 |
| | | | (0.0318) |
| Cooking Setting | | | |
| 2. Separate Building | | | -0.0778 |
| | | | (0.0643) |
| 3. Outdoors | | | -0.0642 |
| | | | (0.0653) |
| Sanitation | | | 0.1045** |
| | | | (0.0531) |
| Water Source | | | -0.0309 |
| | | | (0.0446) |
| Constant | 0.2016** | -0.4032*** | -0.2650 |
| | (0.0993) | (0.1505) | (0.2302) |
| Region Effect | No | No | YES |
| N | 4376 | 4376 | 4374 |
| $R^2$ | 0.0392 | 0.0533 | 0.0752 |

Note: Standard errors are reported in parentheses.
*,**,*** Statistically significant at the 10, 5 and 1% levels respectively.
Weight for Height Z Score (WHZ)
Source: UDHS (2006/2011)

Table 21. Seemingly Unrelated Bivariate Probit Regression Results for Prevalence of ARI and Stunting by Age Cohorts

| | ARI | | | Stunting | | |
|---|---|---|---|---|---|---|
| Variables | 10A: 0 – 12mo | 11A: 12 – 18mo | 12A: 18 – 59mo | 10B: 0 – 12mo | 11B: 12 – 18mo | 12B: 18-59mo |
| Firewood | 0.2377** | 0.1768 | 0.2534*** | 0.0505 | 0.3594** | 0.5090*** |
| | (0.1101) | (0.1683) | (0.0696) | (0.1172) | (0.1697) | (0.0675) |
| Child's Age in Months | 0.1047*** | -0.0903*** | -0.0091*** | 0.0711*** | 0.0624* | -0.0069*** |
| | (0.0117) | (0.0346) | (0.0021) | (0.0141) | (0.0346) | (0.0021) |
| Sex (1 if male, 0 otherwise) | 0.1239 | -0.0557 | -0.0062 | -0.1789** | -0.0954 | -0.2141*** |
| | (0.0821) | (0.1185) | (0.0501) | (0.0894) | (0.1174) | (0.0478) |
| Duration of Breastfeeding | | | | 0.1624 | -0.0029 | -0.0009 |
| | | | | (0.1156) | (0.0027) | (0.0007) |
| Measles Vaccination | | | | -0.1999 | -0.0696 | -0.1328** |
| | | | | (0.1377) | (0.1294) | (0.0607) |
| Vitamin A | | | | -0.0951 | -0.0203 | -0.0254 |
| | | | | (0.0976) | (0.1191) | (0.0503) |
| Constant | -1.5903*** | 0.9251 | -0.4551*** | -16.4779 | -1.1184* | 0.0815 |
| | (0.1740) | (0.5963) | (0.1293) | (10.9785) | (0.6644) | (0.1401) |
| N | 1100 | 487 | 2876 | | | |
| Log-Likelihood | -1139.4362 | -627.4215 | -3568.5615 | | | |

Table 21 continued

| | | | |
|---|---|---|---|
| Corr(ARI, Stunting) | 0.0295 | 0.0099 | 0.0113 |
| | (0.0599) | (0.0759) | (0.0320) |
| $\chi^2$ for ρ(ARI, Stunting) | 0.2423 | 0.0169 | 0.1241 |

Note: Standard errors are presented in parentheses
*,**,*** Statistically significant at the 10, 5 and 1% levels respectively
Acute Respiratory Infection (ARI)
Source: UDHS (2006/2011)

Table 22. Seemingly Unrelated Bivariate Probit Regressions for Prevalence of ARI and Stunting Including Quadratic Age Term

| | ARI | Stunting |
|---|---|---|
| Variables | 13A: Child Characteristics | 13B: Child Characteristics |
| Firewood | 0.2454*** | 0.4034*** |
| | (0.0550) | (0.0553) |
| Child's Age in Months | 0.0211*** | 0.0641*** |
| | (0.0047) | (0.0055) |
| Child's Age in Months (Squared) | -0.0004*** | -0.0009*** |
| | (0.0001) | (0.0001) |
| Sex (1 if male, 0 otherwise) | 0.0227 | -0.1900*** |
| | (0.0399) | (0.0395) |
| Duration of Breastfeeding | | -0.0007 |
| | | (0.0006) |
| Measles Vaccination | | -0.0864* |
| | | (0.0500) |
| Vitamin A | | -0.0354 |
| | | (0.0416) |
| Constant | -0.9229*** | -1.1488 |
| | (0.0942) | (0.1182) |
| N | 4463 | |
| Log-Likelihood | -5395.5784 | |
| Corr(ARI, Stunting) | 0.0198 | |
| | (0.0262) | |
| $\chi^2$ for ρ(ARI, Stunting) | 0.5737 | |

Note: Standard errors are presented in parentheses
*,**,*** Statistically significant at the 10, 5 and 1% levels respectively
Acute Respiratory Infection (ARI)
Source: UDHS (2006/2011)

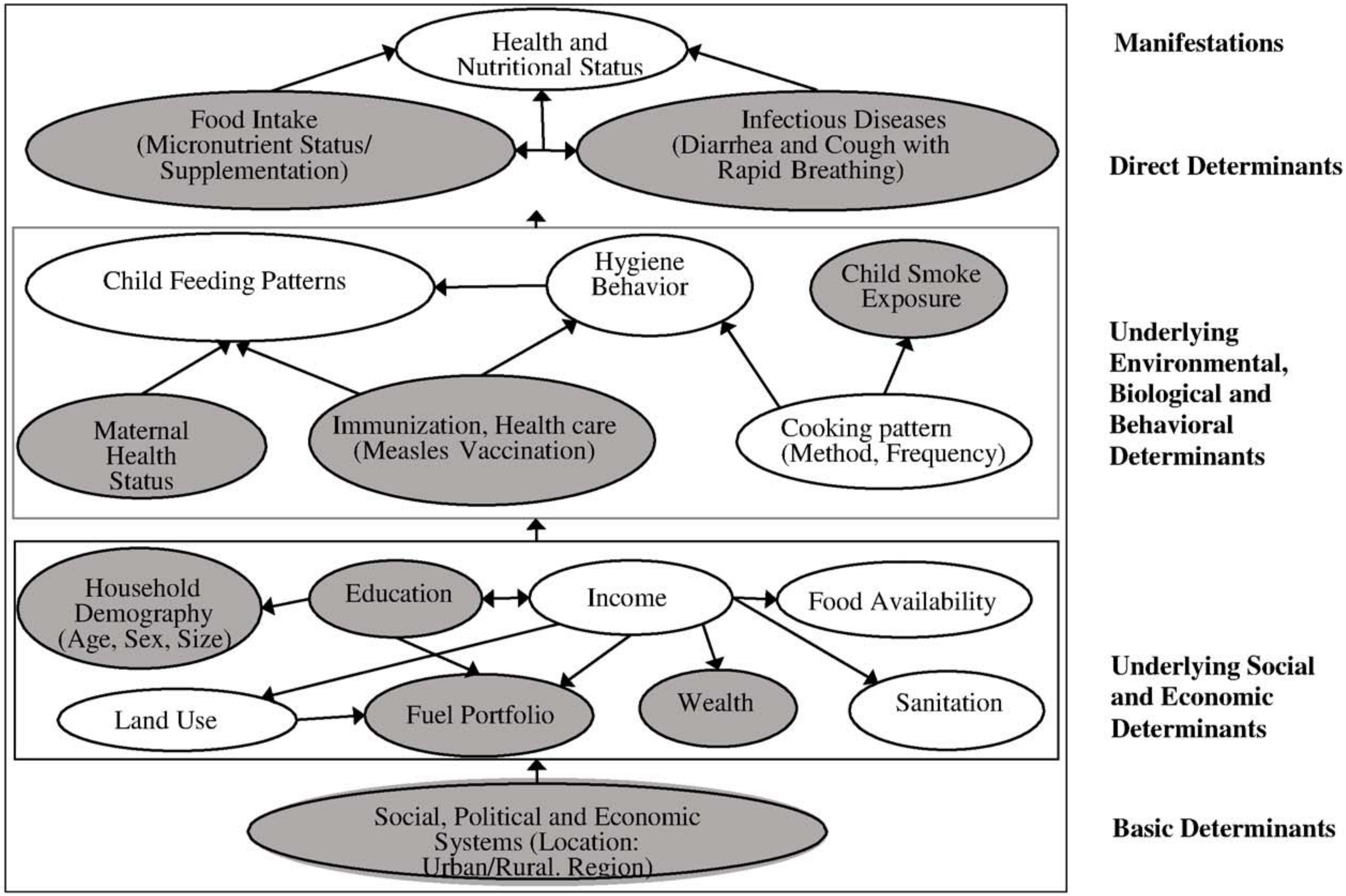


Figure 1. Conceptual Framework and Hypothesis

Modified from FANRPAN (2006), adapted from UNICEF (1998)

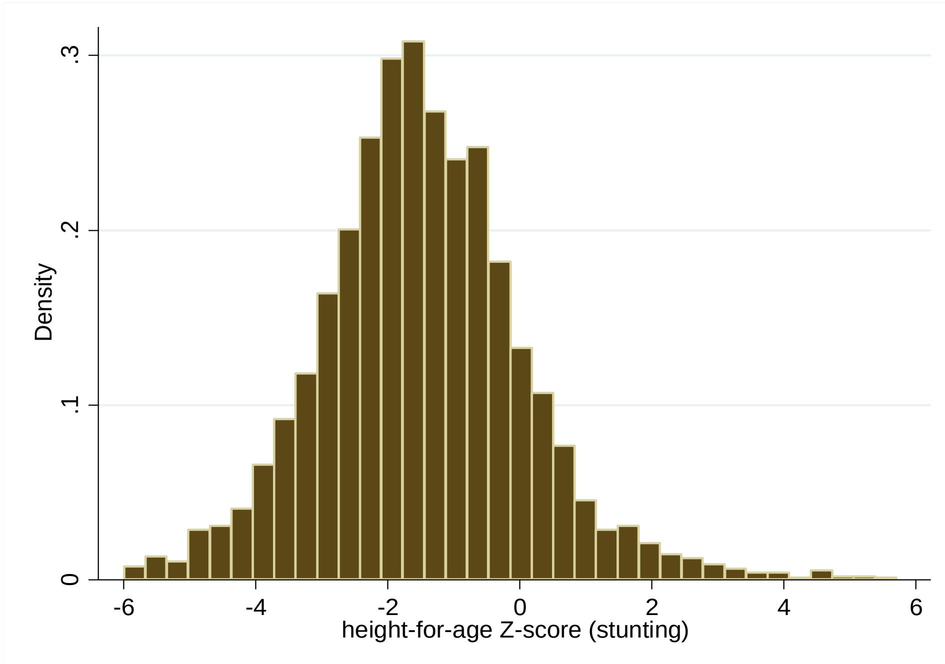


Figure 2. Histogram of Height-for-age Z-score. Source: UDHS (2006/2011).

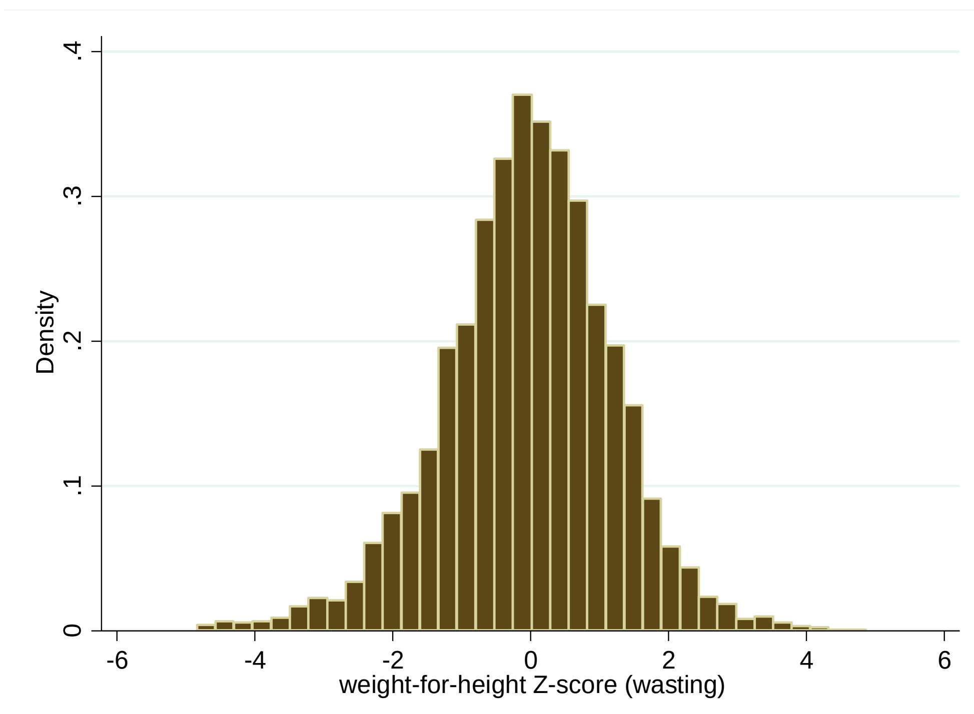


Figure 3. Histogram of Weight-for-height Z-score. Source: UDHS (2006/2011).

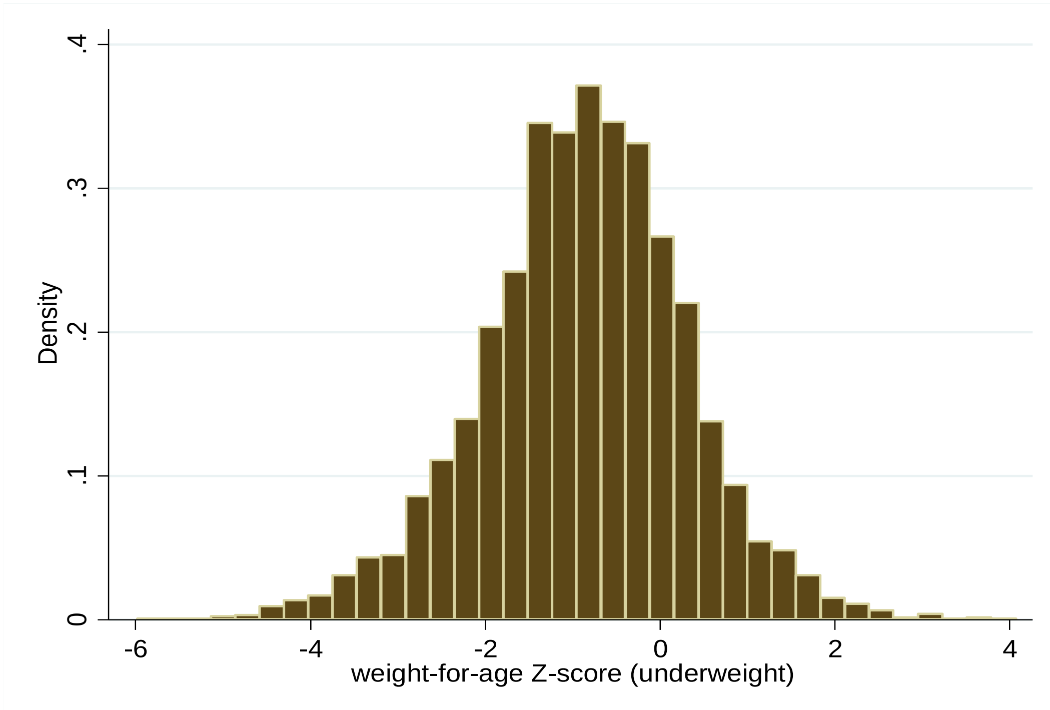


Figure 4. Histogram of Weight-for-age Z score. Source: UDHS (2006/2011).

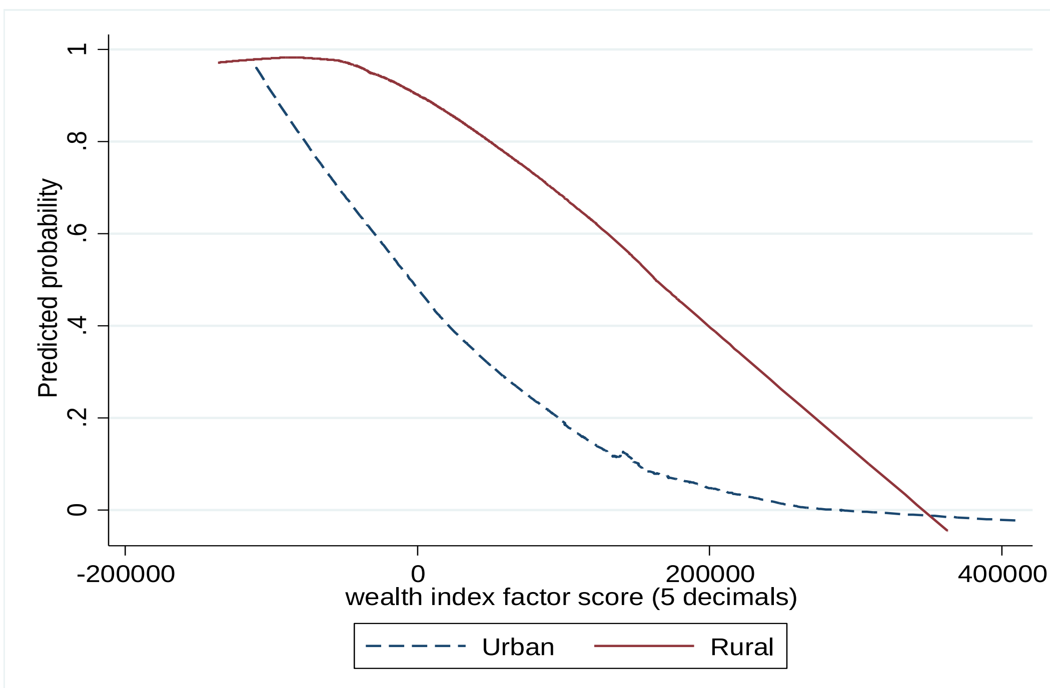


Figure 5. Lowess smoothed values of firewood predicted from wealth index factor by location

Source: UDHS (2006/2011).

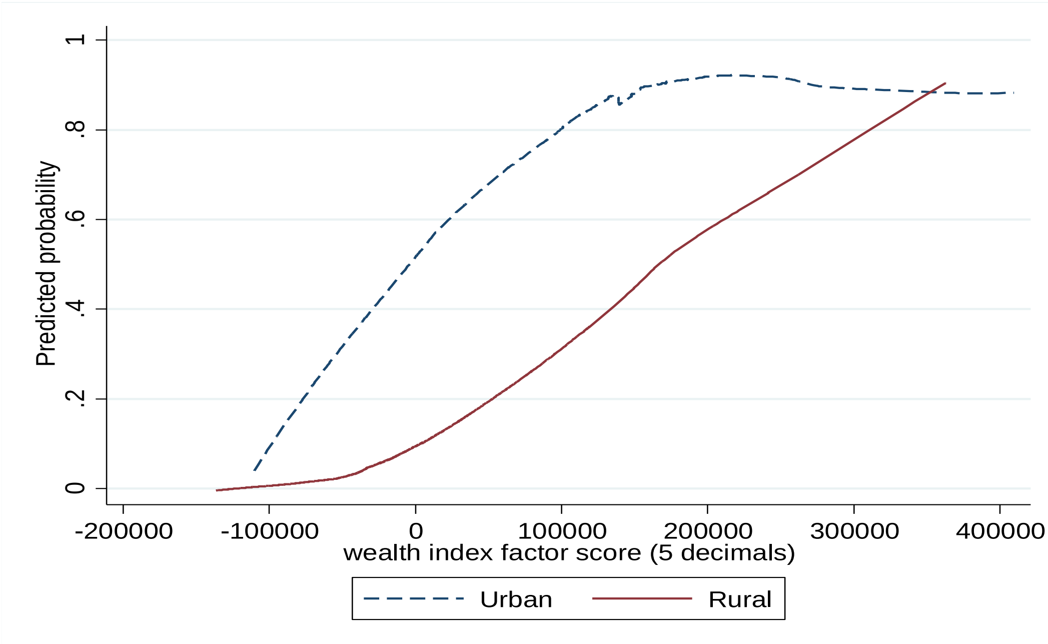


Figure 6. Lowess smoothed values of charcoal use predicted from wealth index factor by location

Source: UDHS (2006/2011).

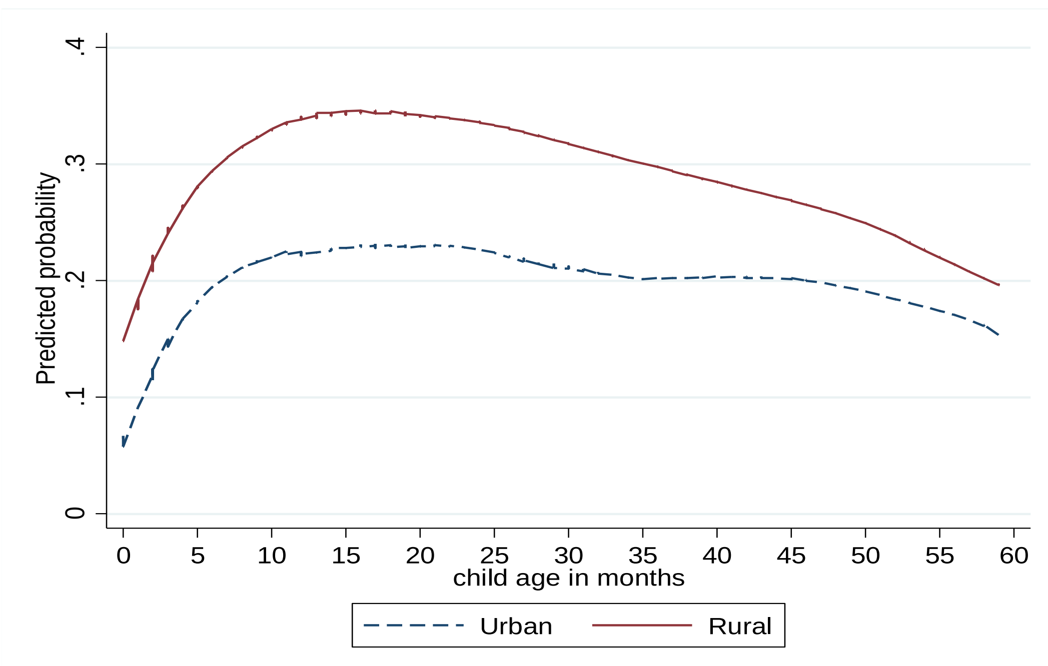


Figure 7. Lowess smoothed values of ARI = 1 predicted from child's age in months by location

Source: UDHS (2006/2011).

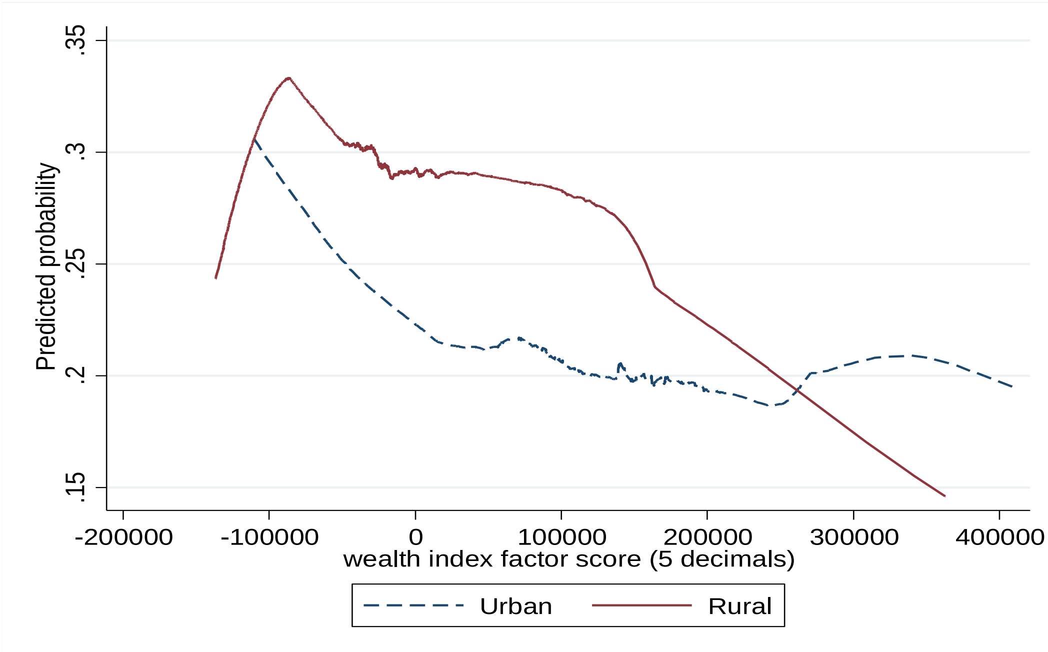


Figure 8. Lowess smoothed values of ARI = 1 predicted from wealth index factor by location

Source: UDHS (2006/2011).

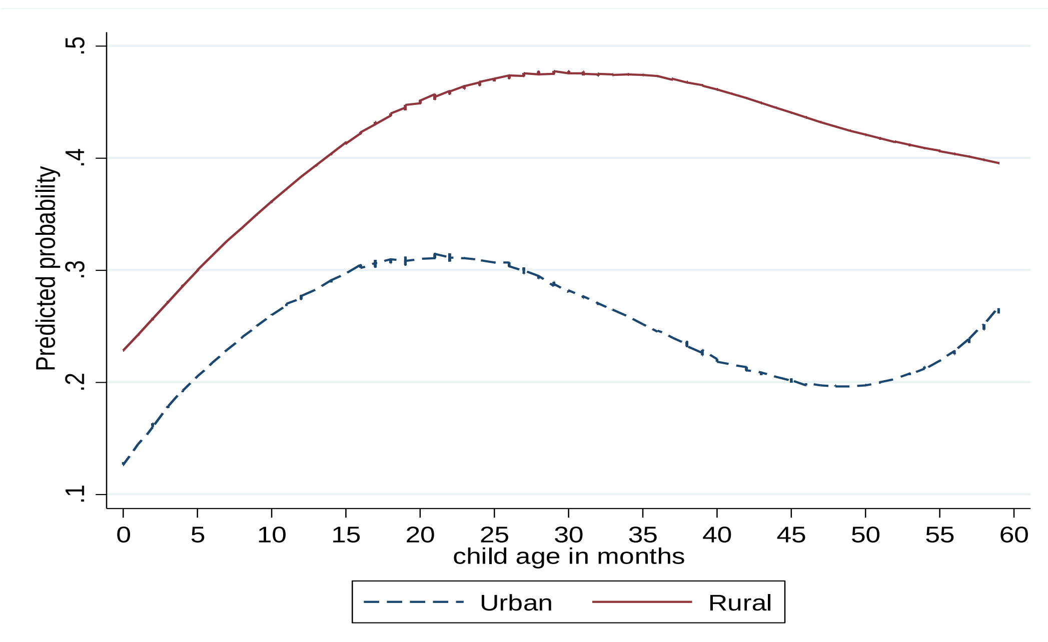


Figure 9. Lowess smoothed values of CIAF = 1 predicted from child's age in months by location

Source: UDHS (2006/2011).


Figure 10. Lowess smoothed values of CIAF = 1 predicted from wealth index factor by location

Source: UDHS (2006/2011).

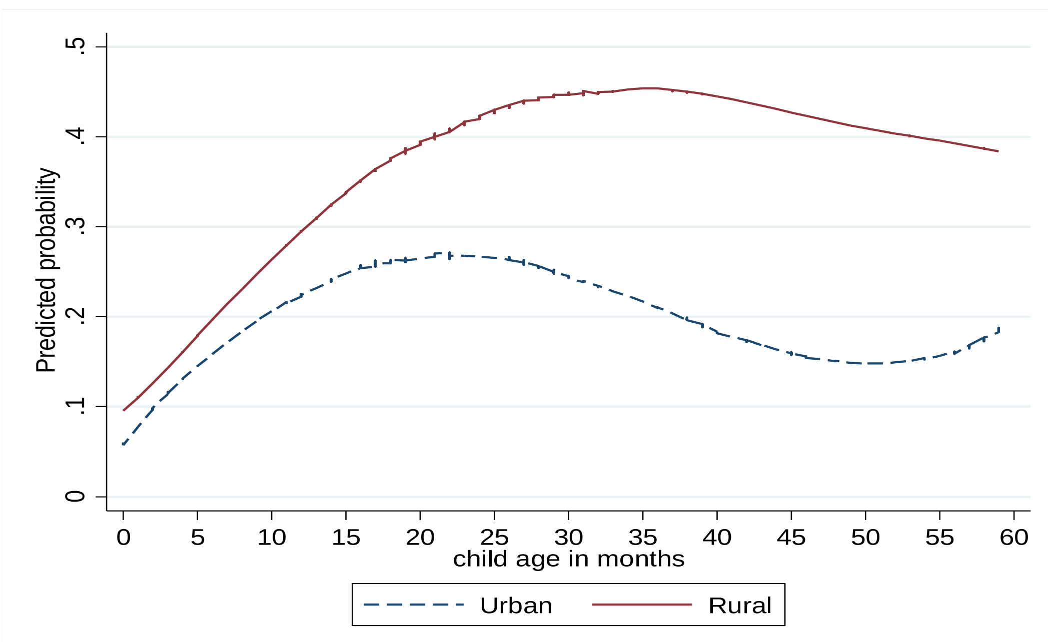


Figure 11. Lowess smoothed values of Stunting = 1 predicted from child's age in months by location

Source: UDHS (2006/2011).

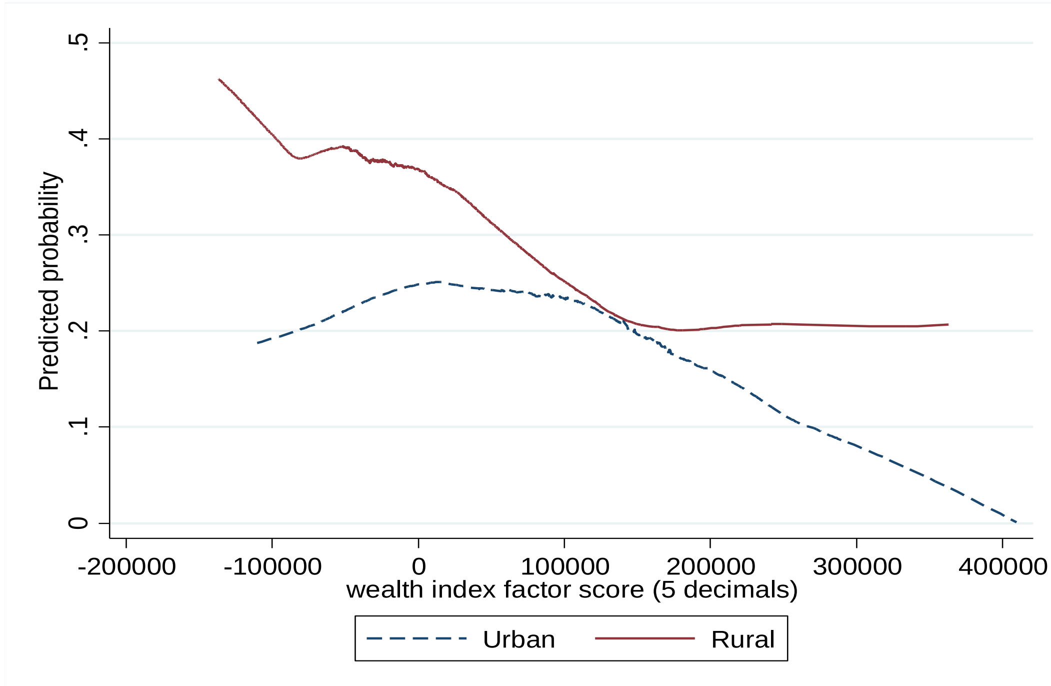


Figure 12. Lowess smoothed values of Stunting = 1 predicted from wealth index factor by location

Source: UDHS (2006/2011).

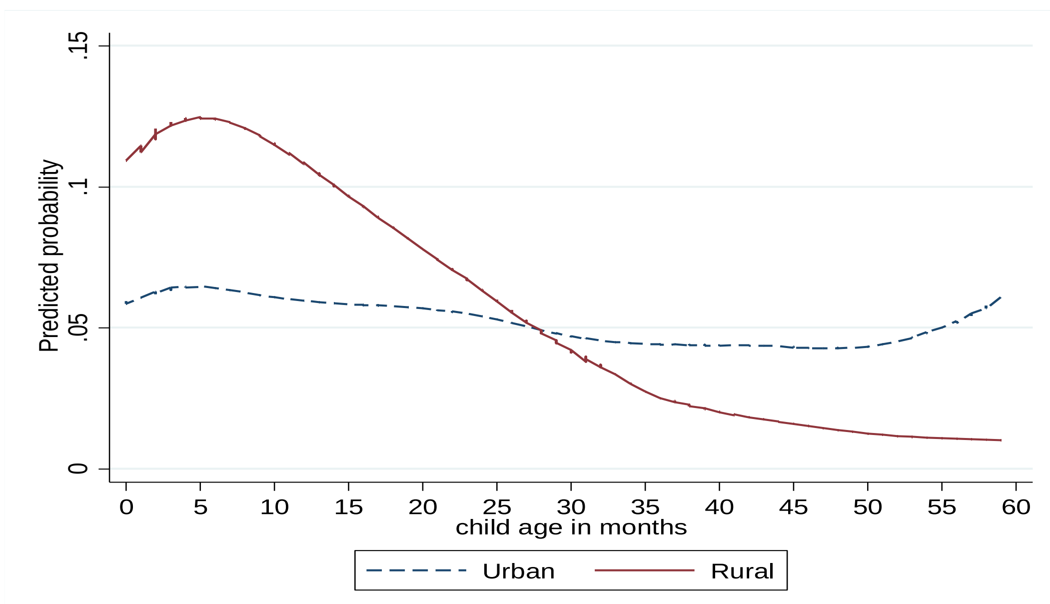


Figure 13. Lowess smoothed values of Wasting = 1 predicted from child's age in months by location

Source: UDHS (2006/2011).

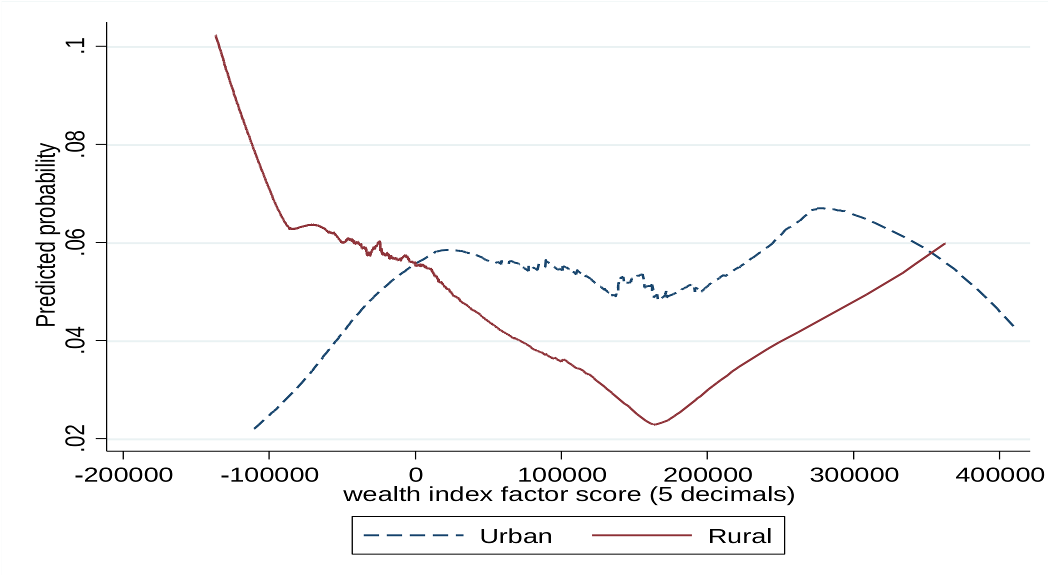


Figure 14. Lowess smoothed values of Wasting = 1 predicted from wealth index factor by location

Source: UDHS (2006/2011).

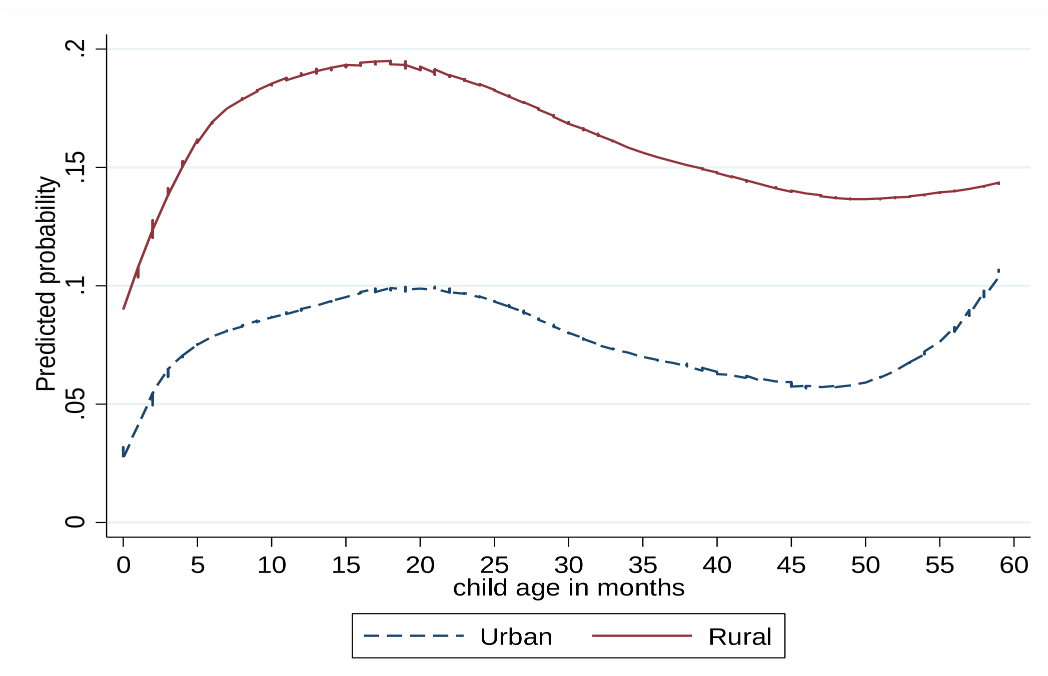


Figure 15. Lowess smoothed values of Underweight = 1 predicted from child's age in months by location

Source: UDHS (2006/2011).

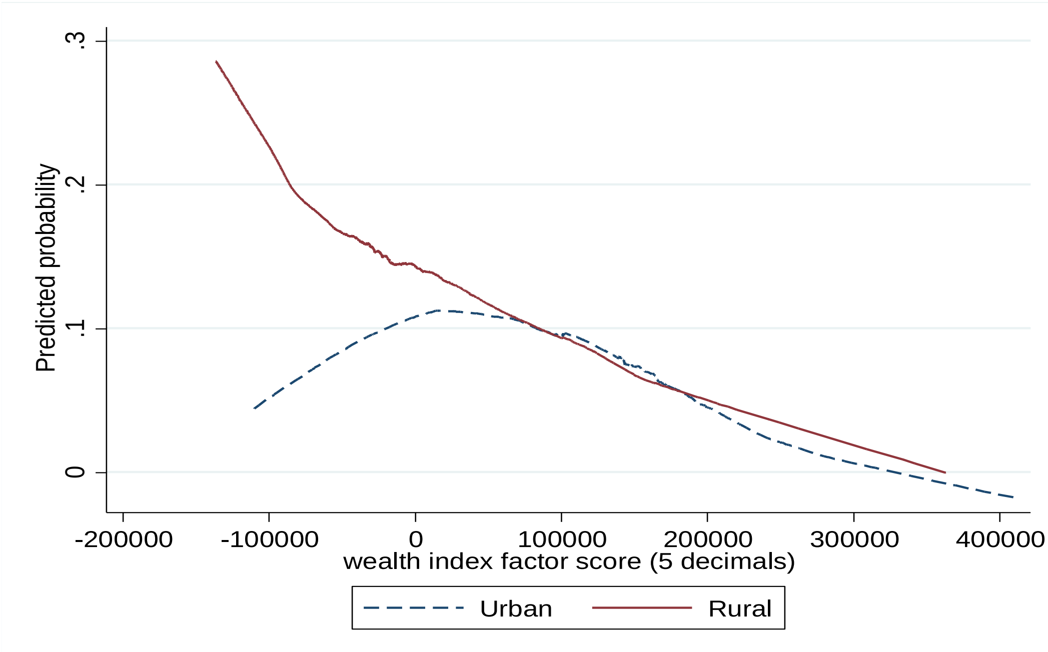


Figure 16. Lowess smoothed values of Underweight = 1 predicted from wealth index factor by location

Source: UDHS (2006/2011).

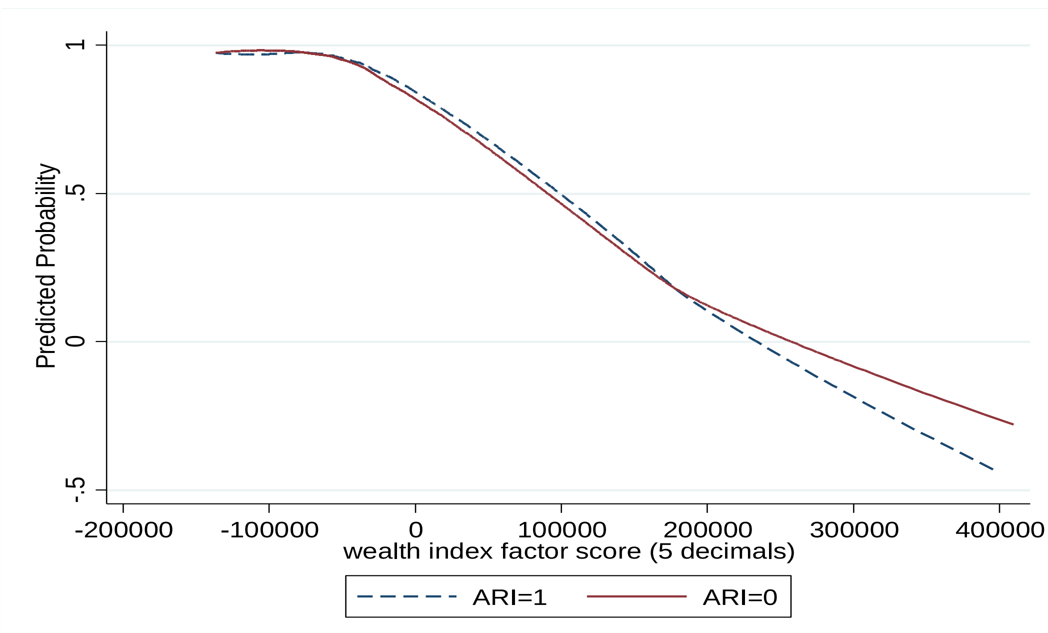


Figure 17. Lowess smoothed values of firewood = 1 predicted from wealth index factor by ARI

Source: UDHS (2006/2011).

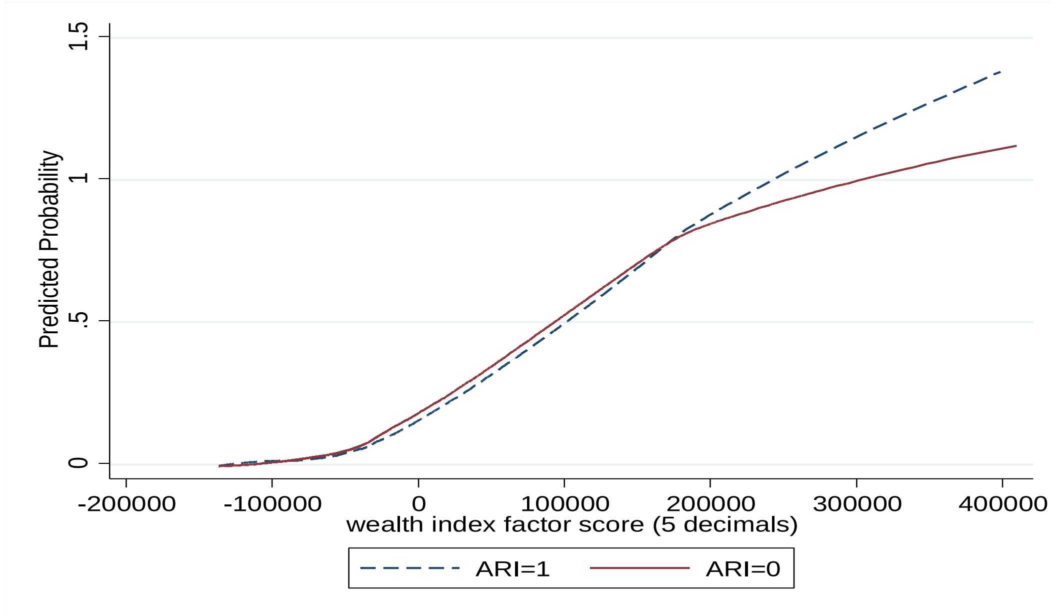


Figure 18. Lowess smoothed values of charcoal = 1 predicted from wealth index factor by ARI

Source: UDHS (2006/2011).

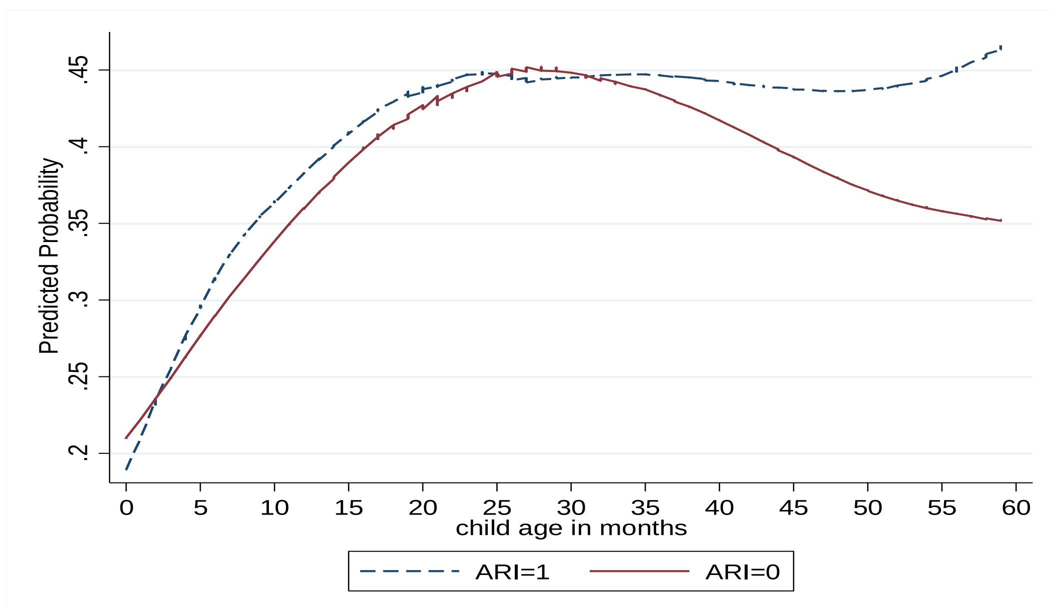


Figure 19. Lowess smoothed values of CIAF = 1 predicted from child's age in months by ARI

Source: UDHS (2006/2011).

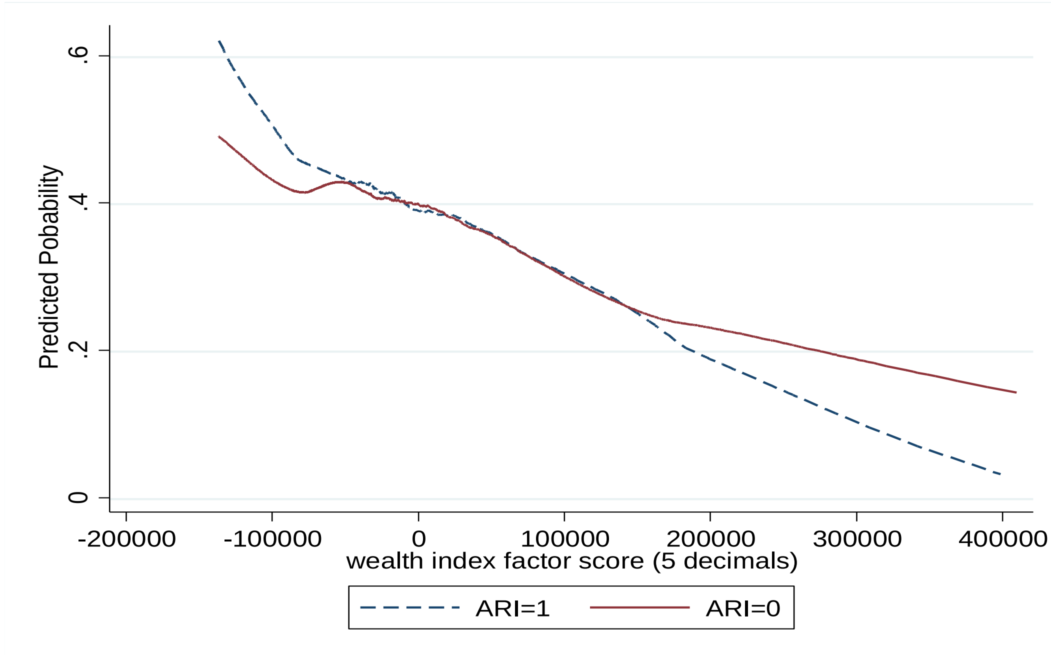


Figure 20. Lowess smoothed values of CIAF = 1 predicted from wealth index factor by ARI

Source: UDHS (2006/2011).

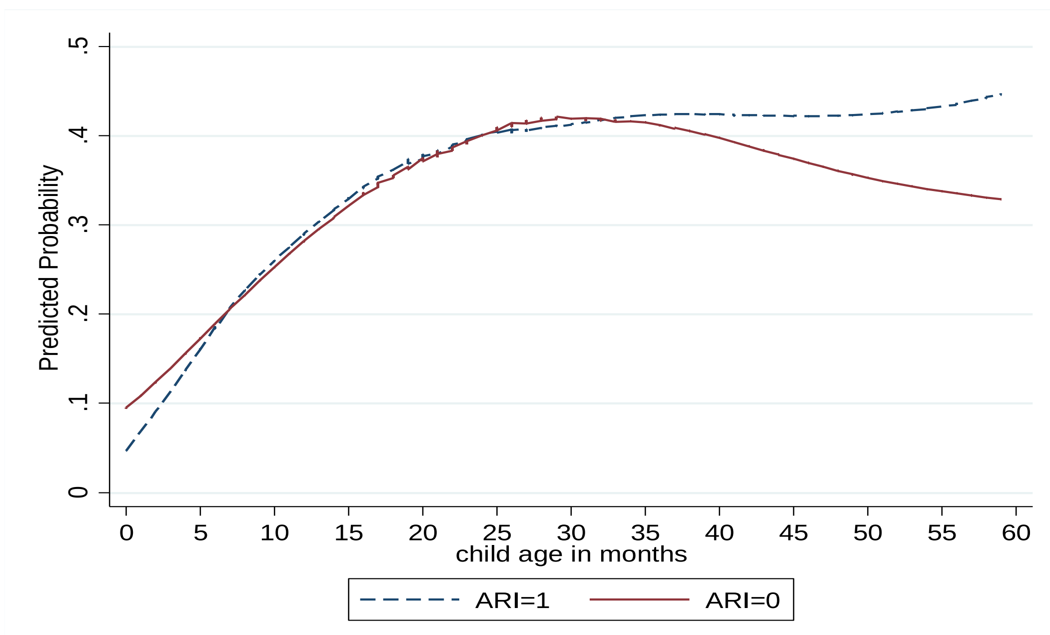


Figure 21. Lowess smoothed values of Stunting = 1 predicted from child's age in months by ARI

Source: UDHS (2006/2011).

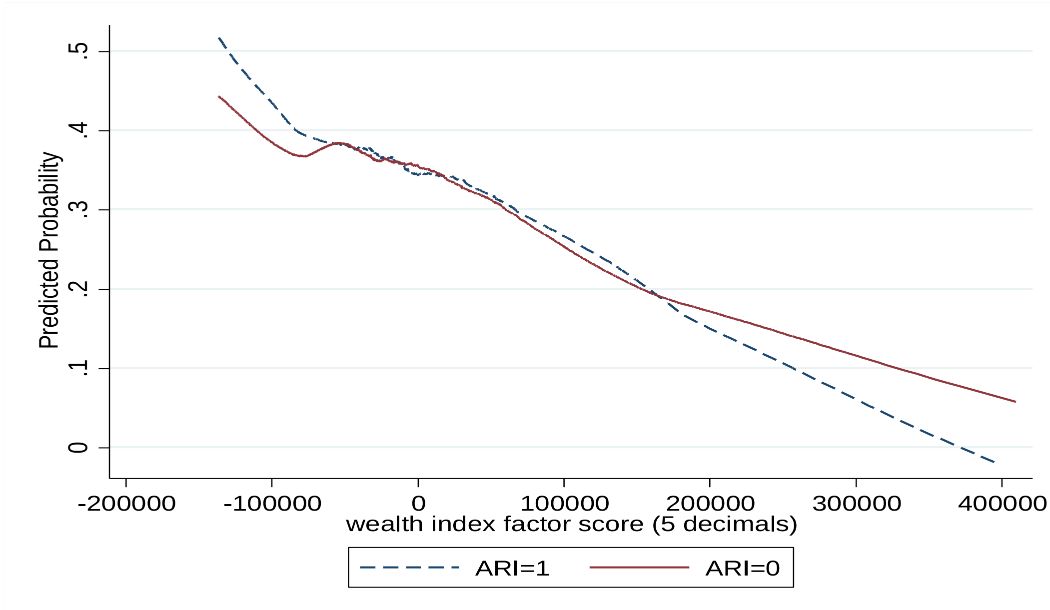


Figure 22. Lowess smoothed values of Stunting = 1 predicted from wealth index factor by ARI

Source: UDHS (2006/2011).

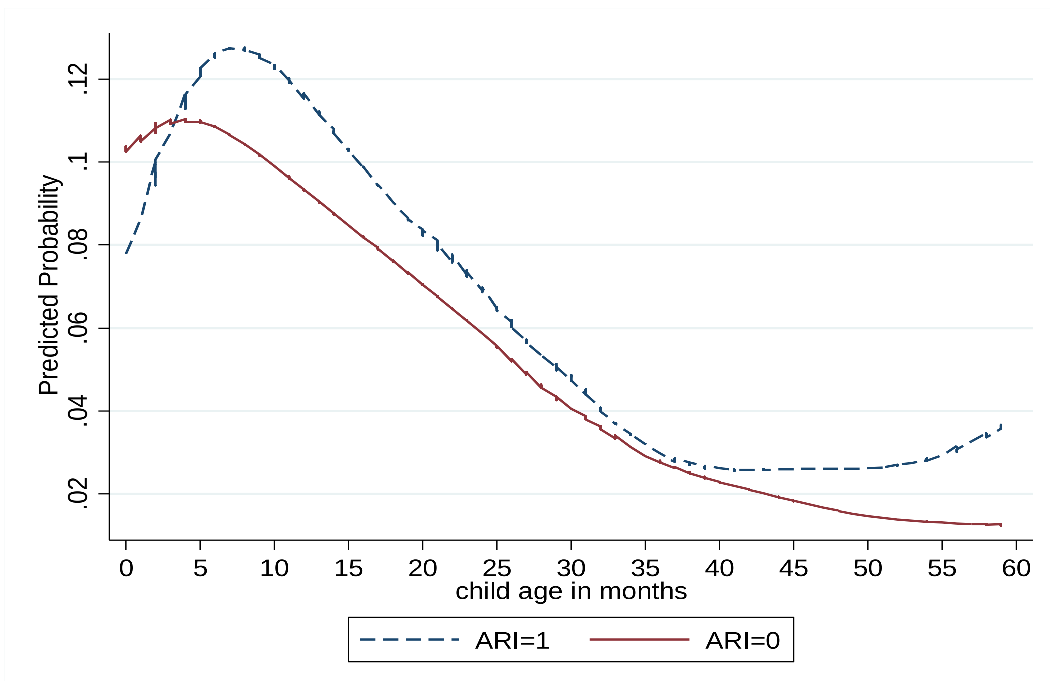


Figure 23. Lowess smoothed values of Wasting = 1 predicted from child's age in months by ARI

Source: UDHS (2006/2011).

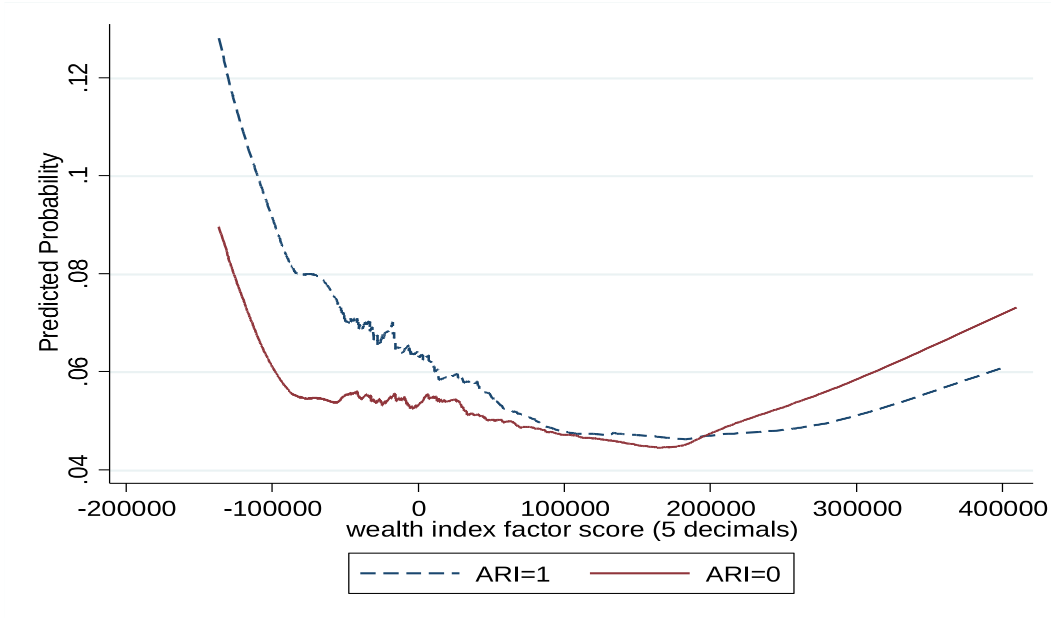


Figure 24. Lowess smoothed values of Wasting = 1 predicted from wealth index factor by ARI

Source: UDHS (2006/2011).

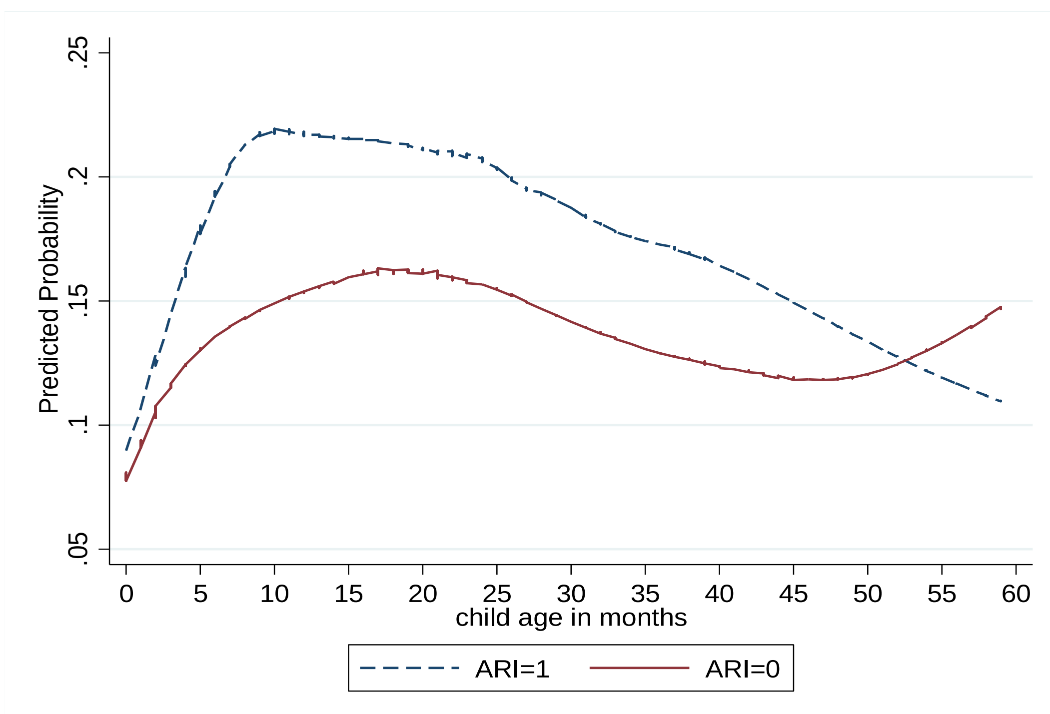


Figure 25. Lowess smoothed values of Underweight = 1 predicted from child's age in months by ARI

Source: UDHS (2006/2011).

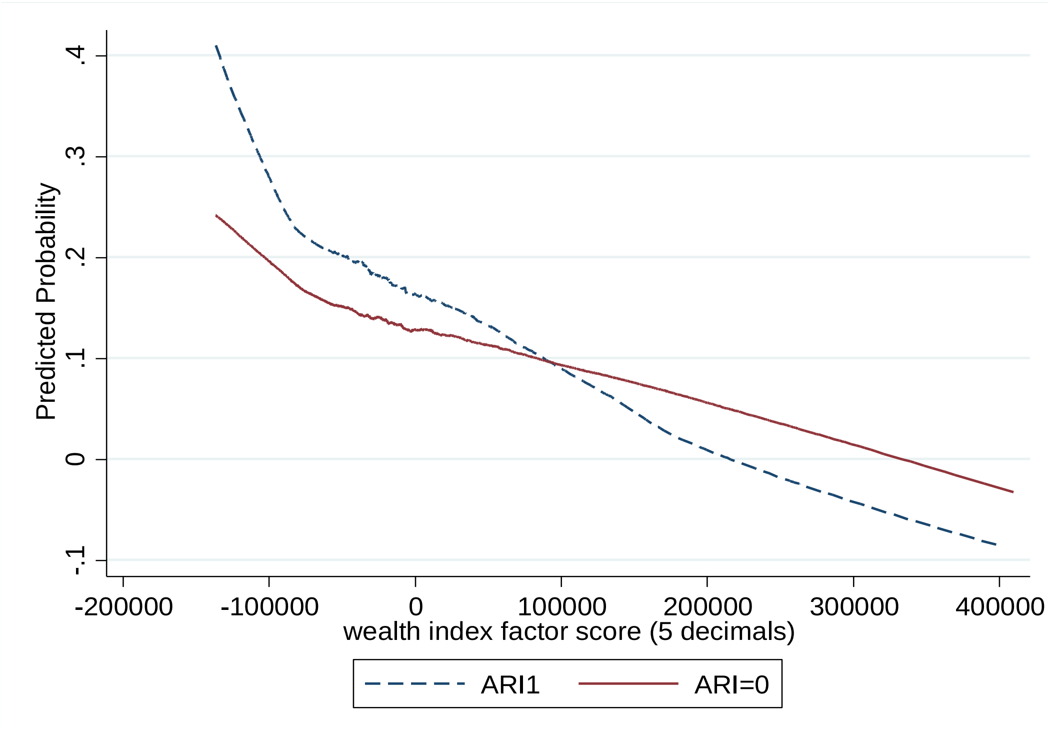


Figure 26. Lowess smoothed values of Underweight = 1 predicted from wealth index factor by ARI

Source: UDHS (2006/2011).

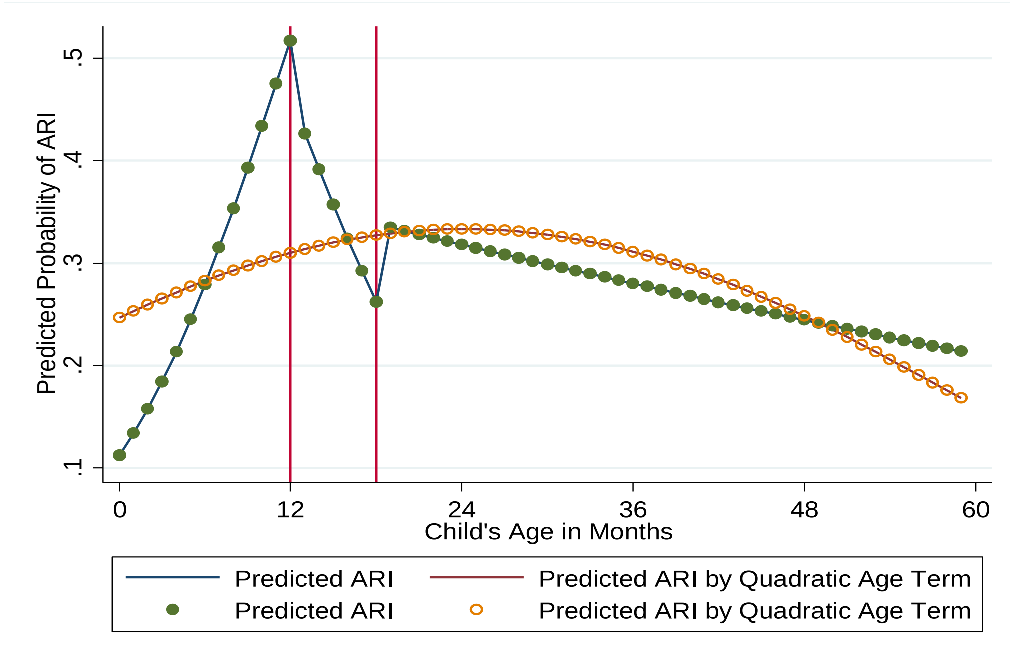


Figure 27. Line connected scatter plots of predicted probability of ARI by child's age in months

Source: UDHS (2006/2011).

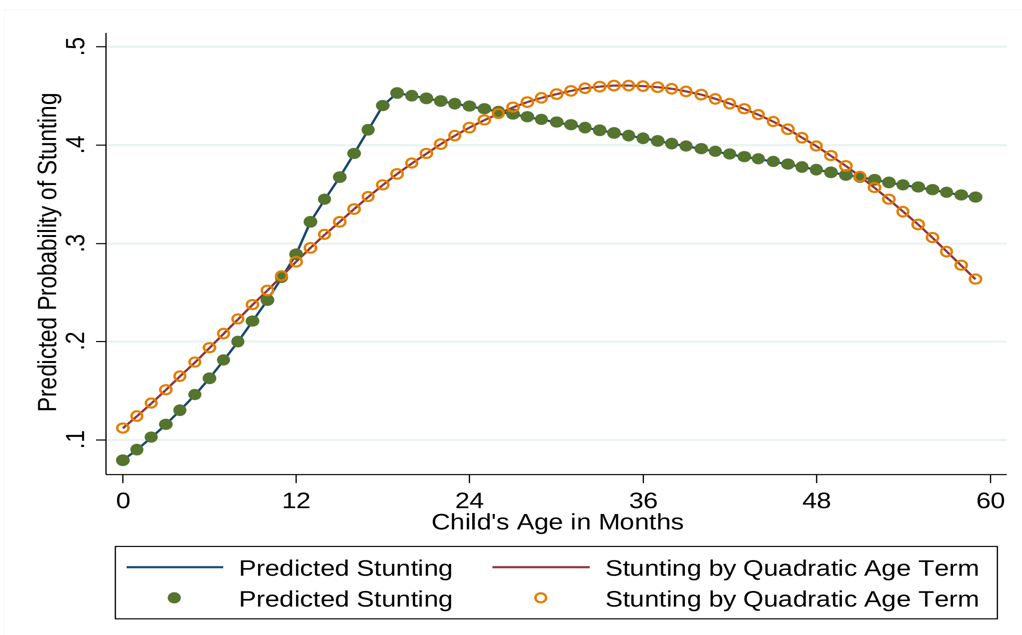


Figure 28. Line connected scatter plots of predicted probability of stunting by child's age in months

Source: UDHS (2006/2011).

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