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DETERMINANTS OF NUTRITION AND HEALTH STATUS OF CHILDREN IN ETHIOPIA: A Multivariate Multilevel Linear Regression Analysis

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Abstract

This study is an attempt to study the determinants of health/nutritional status of children in Ethiopia using data collected in Ethiopia Demographic and Health Survey EDHS (2005). The survey collected information from a total of 5,280 children aged less than 59 months out of which 3108 children were considered in this study.

Depending on our objectives descriptive, multiple linear regression, multilevel linear regression and multivariate multilevel linear regression statistical techniques were used for data analysis using socio-economic, demographic and health and environmental variable as explanatory variables and measures of health/nutrition status with underweight and stunting as response variables.

The results of the analysis show that place of residence, employment status of mother, employment status of partners, age of the child, educational status of mothers, diarrhea, household economic level and source of drinking water were found to be the most important determinants of health/nutritional status of children.

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Acronym

AIDS	Acquired Immunodeficiency Syndrome
Cov	Covariance
EDHS	Ethiopian Demographic and Health Survey
EM	Expectation-maximization
DHS	Demographic and Health Survey
FDRE	Federal Democratic Republic of Ethiopia
HIV	Human Immunodeficiency Virus
IGLS	Iterative Generalized Least Squares
NCHS	National Center for Health Statistics
MDG	Millennium Development Goals
ML	Maximum Likelihood
MVML	Multivariate Multilevel
MVN	Multivariate Normal
MOH	Ministry of Health
OLS	Ordinary Least Squares
RIGLS	Restricted Iterative Generalized Least Squares
SCUK	Save the Children United Kingdom
STD	Sexually Transmitted Diseases
UN	United Nations
UNICEF	United Nations Children’s Fund
US	United States
Var	Variance
WB	World Bank
WHO	World Health Organization
WMS	Welfare Monitoring Survey

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Health and nutrition are important and critical components for developing countries. In addition they are channels through which productivity and distribution goals of developing societies may be pursued effectively. As is often hypothesized, the productivity of low-income persons in work and in human capital information is positively affected by health and nutritional status.

Nutrition and health are important dimensions of human well-being. Malnutrition represents the main health problem in developing countries. Though the word "malnutrition" is associated with both undernutrition and overnutrition (Smith and Haddad, 2000), in this paper it is meant to refer to under nutrition. Malnutrition among women is likely to have a major impact on their own health and on the healthy of their children. Besides her own health, a mother's nutritional status affects her capacity to successfully care for her children (Abey, 1995). Women in the reproductive age group (15-49 years) and children are most vulnerable to malnutrition due to low dietary intakes, inequitable distribution of food within the household, improper food storage and preparation, dietary taboos and infectious diseases (EDHS, 2006). Particularly for women, the high nutritional costs of pregnancy also contribute significantly to their poor nut ritional status (Woldemariam and Timotiwos, 2002).

Woldemariam and Timotiows (2002) performed a comparative study for urban, rural and combined urban and rural children. They identified region of residence, education of mother, economic status of the household and age of the child as determinants of malnutrition and health problems among urban children. For rural children, the analyses showed that region of residence, education of mother, education of partner, age, birth order and preceding birth interval of a child as important predictors of nutrition/health status. The combined urban and rural (national) sample results indicated that region of residence, education of mother, education of father, economic status of the household, age, birth order and birth interval of the child were found to be determinants of child nutrition and health status.

Since children are the economic assets to the world and their future development outcome can be influenced by their nutrition and health status, the mechanism and consequences of malnutrition and health problems need to be understood better. This is true in a country like Ethiopia where malnutrition and health problems are common. Therefore, there is a need to assess the factors associated with nutrition/health status of children so that interventions can be planned to children to achieve growth and development.

Recent illnesses significantly contribute in precipitating malnutrition in marginally nourished children. Diarrhea exerts this influence by depleting the body of fluids. The traditional practice of withholding food from the child suffering from diarrhea diseases also plays an important role. Fever accelerates the onset of malnutrition by reducing food intake and increasing catabolic reactions in the organism (WHO, 1986). Studies in New-Guinea (Han-Am and Sleigh, 1995) and Ethiopia (Genabo et al (1999); Gugsa, 1998) revealed that the nutritional status of children based on height-for-age is associated with the presence of recent symptom of illness, fever and diarrhea.

Diarrhea and other infectious diseases manifested in the form of fever affect both dietary intake and utilization, which may have a negative effect on improved child nutritional status. A study on children's nutritional status (Sommerfelt et. al., 1994) indicated that stunting was highest among children with recent diarrhea.

Past studies on child nutrition and health analysis were mainly descriptive in nature and limited to the study of associations between nutrition/health status with certain nutrition/health-related variables. Few studies have been done on risk factors of malnutrition in children using logistic regression, and most of these studies are based on small-scale survey data concentrated on certain regions.

The present study is based on a recent national data from the 2005 Demographic and Health Survey with reference to children less than 59 months using Univariate Linear Regression, and Univariate and Multivariate Multilevel Linear Regression analysis.

1.2 Statement of the problem

The nutritional and health status of children in Ethiopia are among the worst in the world. For example, almost one in every ten babies born in Ethiopia (97 per 1000) does not survive to celebrate its first birthday, and one in every six children dies before its fifth birthday. As a result, it will be challenging to reach the child survival Millennium Development Goals (reducing child mortality by 3/4) with the current pace of mortality reduction (WB and MoH, 2005).

High malnutrition rates in Ethiopia pose a significant obstacle to achieving better child health outcomes. Based on the 2004 Welfare Monitoring Survey (WMS), out of all children aged 3 to 59 months, the prevalence of wasted, stunted and underweight (their z-score less than -2 standard deviation) at country level are reported as 8.3 percent, 46.9 percent and 37.1 percent, respectively. The figures given show the extent to how much of the country's potential work force is faced with growth retardation.

Even though the problem of child malnutrition in Ethiopia has been sufficiently documented, the reasons behind it are still poorly understood. There is also inconsistency across studies regarding the determinant factors behind child health/nutrition. The researcher shares the idea and the main reason behind the need to study socio-economic, demographic, health and environmental determinants and differentials of health/nutritional status in Ethiopia is, so far, there are not money detailed studies conducted to explore all aspects of health/nutritional status in Ethiopia particularly the effects of socio-economic factors on health problem and malnutrition.

Therefore, this study attempts to investigate the major socio-economic, demographic, health and environmental factors that affect health/nutritional status in Ethiopia.

1.3 Objective of the study

General Objective

The general objective of this study is to inspect the various possible factors and their contribution for the current high prevalence of malnutrition and health problems using the most recent data in Ethiopia.

Specific Objectives

The specific objectives of this study are**:**

1. To identify the most important socio-economic, demographic and health and environmental determinants of child nutrition and health status among children of national level

2. To examine within-regional and between-regional level differences in determining the nutrition and health status of children.

3. To identify the relationship between the types of nutritional status (stunting and underweight) related to various possible factors with respect to the regions and at child levels.

1.4 Significance of the study

The findings from this research are hoped to be useful in many ways. The findings could be helpful for policy making, monitoring and evaluation activities of the government and different concerned agencies.

Since the study will attempt to reveal the major responsible factors and their relative contribution to the malnutrition and health problem of children, the end user governmental and non-governmental organizations could take intervention measures and set appropriate plans to tackle the existing health and nutrition problems by identifying and giving priority for the very poor and vulnerable groups.

This study is expected to contribute its part by filling the information gap concerning health and nutrition in the country. Finally, the study could be used as a stepping stone for further studies.

1.5 Limitations of the study

Although many factors affect health problem and malnutrition as indicated by different studies in different countries by including different social, economic, political, cultural, demographic, physiological, biological, reproductive health rights, family planning policies/programs etc., this study is undertaken to explore a few of the socio-economic, demographic, health and environmental determinants and differentials of health/nutritional status in Ethiopia. In this study, the analysis is carried out using MLwiN software but this software does not provide model diagnostic tests except likelihood ratio test. Thus, we only checked goodness of fit by using deviance-based chi-squared test. The data, we use in this study, is EDHS 2004/05. Thus, the results may not necessarily reflect the current situation of Ethiopia

1.6 Organization of the Study

This study is presented in five chapters. The first chapter gives a general background of the study, statement of the problem, objective, its significance and limitation of the study. Chapter 2 deals with the review of literature on health and nutrition in Ethiopia and the rest of the world, whereas chapter three specifies the data and methodology of the study such as sources of data and variables to be included in the study with their coding and description. Methods of data analysis are also described in this chapter. Chapter 4 reports results from the statistical data analysis and provides discussions. Finally, the last chapter presents discussion, conclusion and policy recommendations based on the findings of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Concepts and Definitions

The words “nutrition” and “health” are used interchangeably here (as is used in the literature the World Health Organization, 2005) for both outcomes are too related that it is difficult to disentangle one from the other, and thus both may signify the same thing when children are considered.

The word “anthropometric” is generally meant to represent the measure of people’s growth indicators such as weights and heights (related to their age and sex). It is used for growth assessment and is a single measurement that best defines the health/nutritional status of a child (Blossner and De Onis, 2005). According to this measure, the nutritional/health status of children is determined by comparing growth indicators with the distribution of the same indicators for “healthy” (as reference group), and identifying “extreme” or “abnormal” departures from this distribution. The international reference standard that is most commonly used (and recommended by the WHO) is that of the data on the weights and heights of a statistically valid population (US National Center for Health Statistics (NCHS)) of healthy infants and children in the US.

There are three ways of expressing these comparisons: Z-score (standard deviation (SD) score), percent of median, and percentile. But the interest here is on the SD score (Z-score) and it is defined as the difference between the value for an individual and the median value of the reference population for the same age, height, or weight divided by the standard deviation of the reference population. Based on this comparison method, the three most commonly used anthropometric indicators for infants and children are:

1) Weight-for-height (W/H): measures body mass relative to height, without making use of age data and represents a short-term indicator useful to monitor short-term changes in nutritional status. It exhibits the situation of acute malnutrition or ‘wasting’. Wasting is usually caused by a recent nutritional deficiency and may manifest significant seasonal variations according to changes in the availability of food or disease prevalence (Cogill, 2001).

2) Height-for-age (H/A): is a longer-term index and represents linear growth of a child. It gives information about chronic malnutrition or ‘stunting’ which reflects the accumulation of past outcomes (Cogill, 2001).

3) Weight-for-age (W/A): Measures body weight relative to age, and is a composite measure of the other two useful to assess nutritional changes over time, so it can confound short and long-term health problems. It is an index of both acute and chronic malnutrition (Cogill, 2001). It provides the information about ‘underweight’.

The cut-off point to define abnormal anthropometry with Z- scores is -2 standard deviations. A more general rule of thumb for evaluating anthropometric Z-scores has been developed by WHO, with a score of less than -3 indicating “severe” malnutrition, between -3 and -2.01 “moderate” malnutrition, -2 to -1.01 “mild” malnutrition and -1 and above considered normal.

2.2 Determinants of Child Health/Nutrition

Various studies in different/same countries may find different results over the importance of the determinant factors behind children’s nutrition and health outcomes. Estimates may differ depending on various factors including the nature of the data and estimating methodology.

A variety of factors starting from the national level down to the individual interplay in the causation of malnutrition and health problem (UNICEF, 1990). Factors that are contributing to health problem and malnutrition may differ among regions, communities and over time. Identifying the underlying causes of health problem and malnutrition in a particular locality is important to solve the nutritional and health problems.

Various studies on nutrition have been undertaken and conclusions were reached by different scholars in the past regarding predictors of health and nutritional status. The detailed literature review presented below focuses on the socioeconomic, demographic, and health and environmental determinants of malnutrition and health problem in children.

2.2.1 Demographic Characteristics

Most studies report that demographic characteristics such as age, sex and birth order and interval are important determinants of nutrition/health status.

Studies show that while the main causes of malnutrition appear to change with age of children, in most cases older children are found to be associated with increased malnutrition. For example, in Ethiopia report on health and poverty by WB and MOH (2005) using descriptive statistical method show that older children have a higher likelihood of being underweight and stunted relative to children who are less than a year old. And also children's nutritional status is more sensitive for some factors at specific age. For example, during the first 4 or 6 months feeding practices and mother's ability to care for the child are the main determinants of child growth. After the age at which the child starts supplementary feeding (from age 4 to 6 months) through 2 years of age the major influences are exposure to infectious diseases. After 2 years of age household food securities have major effect (UN, 1985). Cumulative indicators of growth retardation, such as stunting and underweight, are positively related to age, with the lower values achieved by less than 6 months age groups (Pelletier, 1991).

On the contrary, Christiaensen and Alderman's (2001) study using logistic regression analysis found that a child's standardized height deteriorates up to the age of three, and slightly improves afterwards.

At country level, all the four welfare monitoring surveys from 1996-2004 using descriptive statistics have revealed that boys are more vulnerable to malnutrition than girls with respect to the three indices (wasting, stunting, and underweight). Similar results are also reported from some case studies and official surveys (Sentayehu, 1994; Christiaensen and Alderman, 2001; Alemu et al. 2005a; Alemu et al. 2005b). Various reasons behind this gender differential are given in the literature. Alemu et al. (2005a), for example, argue that this could be due to genetic differences between male and female children and, due to girls' greater access to food through their gender-ascribed role in contributing to food preparation.

However, using the 2000 Ethiopia Demographic and Health Survey data, Silva (2005) did not find the coefficient on the child's gender to be significant in any of the regressions, suggesting there is no gender bias affecting the nutritional status of children in Ethiopia. Similarly, Bilisuma (2004), using probit model, could not find sex of a child to have a significant impact on the probability of being stunted.

Finally, considering age and gender together, a relatively different result was reported by Abay Asfaw (1995) using longitudinal analysis. Using data collected from four regions of rural Ethiopia, he studied how poverty affects the health status and the health care demand behaviour of households. The finding is that instead of gender and age, relation to the head of the household is an important factor that affects the health status, demand for medical care, and provider choice of households. Since immediate family members are more likely to report illness, to get treatment, and more likely to visit modern health care providers especially private clinics than other family members.

In combination with other factors, high birth order and low birth intervals are reported to have their share in poor childhood health/nutrition outcomes. According to the draft report on the health sector MDGs needs assessment (FDRE, 2004) and Woldemariam and Timotiows (2002) using descriptive and logistic regression analysis, respectively, demonstrated that high birth order and close spacing imply uninterrupted pregnancy and breast feeding and, this depletes women biologically and drains their nutritional resources. These lead to low birth weight which is a key factor in both infant and under-five mortalities, death being more prevalent among smaller children. Close spacing may also have a health effect on the previous child, who may be prematurely weaned if the mother becomes pregnant again too early.

Using Young Lives data of children between the age of 6 and 18 months in Peruvian, Alemu et al. (2005a) did not find birth order to be significantly associated with any of the three indicators considered (wasting, stunting, and underweight) for the whole sample by using logistic regression. However, the results stratified by location show that birth order is associated with wasting and underweight for urban children, while the likelihood of being wasted decreases with higher birth order in rural areas.

On the other hand, unlike expectations, based on the National Rural Nutrition Survey of 1992 on Sidamo, Sentayehu (1994) by using linear regression analysis found positive sign of birth order on height-for-age and weight- for-age equation. The sign is unexpected because high birth order is expected to adversely affect the quantity and quality of resources that could be allocated to the children in the household.

Using data which came from four separate household surveys carried out in three rural provinces of the Philippines in 1983-84 over 800 households, Senauer and Garcia (1991) utilized Weighted Least Square and Fixed Effects models to see the determinants of nutritional and health status of children. In this study, higher birth order children were found to be suffering in terms of the long run health status (height-for-age). The authors argued that this could be presumably due to the increased burden on family resources.

2.2.2 Socioeconomic Characteristics

Socioeconomic characteristics such as household economic status, maternal socioeconomic characteristics (mothers' education, mothers' employment status and their household status relative to men), household size, etc are important in child health outcomes.

The economic status of a household where a child lives has been identified as one of the key determinants of child nutritional status. Smith et al. (2005) using logistic analysis showed that household economic status significantly affects access to food (a necessary condition for food security). It also dictates possession and utilization of child care resources on a sustainable basis.

Most of the studies in Ethiopia including Christiaensen and Alderman (2001), SCUK (2002), Woldemariam and Timotewos (2002), Bilisuma (2004), Alemu et al. (2005b), Abay Asfaw (1995), and Silva (2005) found household wealth/income as an important determinant of child nutritional/health status. Because, according to SCUK (2002), for example, better off households have better access to food and higher cash incomes than poor households, allowing them a better quality diet, better access to medical care and more money to spend on essential non-food items such as schooling, clothing and hygiene products. The studies mentioned above proxy wealth/income in either one or the other of the following variables: housing quality, cattle and land ownership/rental, households' access to food, cash income/expenditure etc.

For example, using data from the 1986 Brazilian Demographic and Health Survey, Thomas et al. (1990b) found total income to have a positive and significant effect on child height in both urban and rural sectors and the effect is much larger in magnitude in the rural sector. On the contrary, Abdulhamid (1996) was unable to establish a significant relationship between poverty (income) and nutritional status of children in urban Ethiopia.

Using data from four regions of Brazil, Thomas et al. (1990b) attempted to estimate the impact of household characteristics on child height and survival. Applying the quasi-maximum likelihood estimation techniques for the binomial model and instrumenting income by logarithm of household expenditure and including unearned income, its square and a set of month dummies, income appears to have no effect on child height in all four of the regions.

Consistently, as food availability is one of household resources, both Alderman (1990) and Maxwell et al. (2000) did not found it to be a significant factor; rather care and health were find to be important inputs. Moreover, Maxwell et al. (2000) did not find higher incomes leading to significantly improved care practices and behaviours.

In many developing countries particularly in Africa, tradition has laid the responsibility of child care on women which begins at conception and continues until infancy, teenage and adulthood (Oyekale and Oyekale, 2000). The implication is that women are key players in the growth and development of a child. In enhancing the quality of care and nutritional status of children, the role of mothers' education is widely recognized. Education improves the ability of mothers to implement simple health knowledge and facilitates their capacity to manipulate their environment including interaction with medical personnel. Furthermore, educated women have greater control over health choices for their children.

Smith and Haddad (2000) using logistic regression analysis showed that education of women has several positive effects on the quality of care rendered to children since women are the main care takers of children. Their ability to process information, acquire skills, and model positive caring behaviour improves with education. Educated women use health care facilities, interact more effectively with health professionals, comply with treatment recommendations, and keep their environment clean. Also, more educated mothers are committed to child care and interact very well with their children.

Using household data from three consecutive welfare monitoring surveys of Ethiopia over the period 1996-1998, Christiaensen and Alderman (2001) using linear regression analysis found that both female and male adult (parental) education has a strong positive and statistically significant effect on the child's nutritional status, and the effect of female education is about twice as large as that of male education. This study also shows that maternal nutritional knowledge is key determinants of chronic child malnutrition in Ethiopia. Other studies also report similar results from female's education (SCUK, 2002; Woldemariam and Timotiows, 2002; Alemu et al., 2005b; Silva, 2005). For example, using woreda level data on children under age of 24 months, SCUK(2002) confirmed that children whose mothers attended school were less likely to be malnourished than the children of uneducated mothers.

Nevertheless, there are some studies which could not find a significant relationship between female's education and child nutritional status (e.g. Sentayehu, 1994). Various reasons could be attached to this result. According to SCUK (2002), for instance, this could be because, although educating mothers (and other care givers) will undoubtedly lead to an improvement in the way some young children are cared for, many mothers will never be able to act on their new knowledge because they are simply poor. This means that poverty could cause bottlenecks, not allowing other public policies to influence child health (Attansio et al., 1992).

Conceptually, the status of women is multidimensional (Mason, 1986). Smith et al. (2005) define women's status as the relative power of women in household, communities, and nations they live in. The status of women is an important determinant of two resources for care: their physical and mental health status, and control over household resources (Smith and Haddad, 2000). The physical conditions of women strongly affect the quality of care they provide to their children even before they are born. Poor physical and mental status of women constrains the quality of care rendered to their children which includes the quality of breast feeding. On the other hand, women's control over resources promotes household food security and nutrition because women show a tendency to spend resources on nutrition inputs such as food (Haddad, 1999). Improved control over resources gives women a better opportunity to provide good care which includes better food preparation and storage practices, hygienic practices, improved care for children during illness (including diagnosis of illness, care seeking and home treatment), and motivation for supporting child development.

Weak control over household resources, tighter constraint on time, restricted access to information and health services, poor mental health, and lack of self confidence and self esteem typically characterize women with relatively lower status which in turn reflect on their children's health and the quality of care provided (Smith et al. (2005)).

The effect of maternal employment on the well being of children has been controversial and it appears difficult to determine the net effect. Crepinsek and Burstein (2004) using logistic regression analysis underscored that employment of mothers can have both positive and negative implication on children's dietary intake.

On the one hand, employment of mothers adds to family income and this may help to ensure stable supply of quality food through increased expenditure. On the other hand, employment status of women (care giver) is found to be insignificant in some studies (see Alemu et al., 2005a; Bilisuma, 2004; Woldemariam and Timotewos, 2002). It is argued that this could be because the time allocated to earning income may be at the expense of time spent in feeding and caring for children, and thus the net effect of these two opposing effects makes employment status of the caregiver an insignificant variable. The presence of other adults in a household, household's income, net of a mother's earning and age of children are likely to affect the net effect of maternal employment on children nutrition/health status (Crepinsek and Burstein (2004).

Household size is also important in the analysis of child nutritional and health status for it has direct implications on household resources. Senauer and Garcia (1991) using linear regression analysis found household size to have a significant positive impact on height of children. The authors argue that this could be because household full income is a function of wage rates and the number of economically active family members, and thus this variable may be reflecting a full income effect.

On the other hand, as household size gets larger there is a big chance of having economically inactive members in the household and this leads to an adverse impact on the available resources and thereby on child nutrition outcomes. For example, according to Alderman (1990) in Ghana, those children in households with a full sibling less than 2 years of age were found to be significantly shorter than cohorts without such a sibling implying the influence of prenatal conditions or competition for resources.

2.2.3 Health and Environmental Characteristics

Health and environmental characteristics including illnesses, sanitation and water, toilet facilities and health care facilities at community as well as at household level is important for their direct and spill over effects on child health/nutrition.

Access to unsafe water and unsanitary disposal of wastes are regarded as the main causes of infectious diseases such as diarrhea and intestinal parasites (UNICEF cited in Smith et al, 2005). Where there is a better access to safe water and quality sanitation, the incidence of various illnesses will decline (Smith and Haddad, 2000). World Bank (2006) stated that improving access and quality of safe water not only reduces transmission of waterborne diseases but also saves women the extra time they spend on carrying water which can be allotted to child care and feeding or income generating activities.

Silva (2005) examined the impact of access to basic environmental services, such as water and sanitation, on children's nutritional status using probit analysis and these are found to be insignificant. However, Silva noted that the results for the model including community environmental sample indicate the coefficients on the proportion of households with access to these services are highly significant in the underweight equations suggesting a spill over effect of other household's access to these services.

Christiaensen and Alderman (2001) found possession of a tap and a flush toilet to have a positive effect on child height. However, access to other sources of drinking water which are generally deemed safe such as public taps and protected wells were not found to positively affect children's height. Similar results for underweight are also found by Woldemariam and Timotiwos, 2002; Alemu et al, 2005a.

Considering usage of a tap and a flush toilet, opposite results to Christiaensen and Alderman (2001) are reported in Alemu et al. (2005a) and Alemu et al (2005b) for the case of wasting in urban and rural areas, respectively. The reason suggested for the former is that it could be because of the unhealthy conditions of communal latrines in slum areas, while the rural case is assumed that people may still prefer to use the open field rather than unfamiliar pit latrines.

Many studies use the distance between the household's home and the nearest health facility to proxy for access to health care (see Christiaensen and Alderman, 2001; Alemu et al, 2005a, Alemu et al, 2005b). In addition to these studies, however, Collier et al., 2002 and Abay Asfaw (1995) argue that usage of health services is sensitive not just to the distance to the nearest facility but also the quality (such as availability of material inputs and drugs, the number and qualification of staff, user fees, etc) of care provided.

As a result, studies report the impact of access to healthcare (proxied by the distance variable) on child health/nutrition to be either insignificant or give result in the counter-intuitive direction. For example, while Christiaensen and Alderman (2001) found no effect of the proximity of a health clinic on children's height, Alemu et al. (2005a) found that communities with better access to public health facilities were having a higher incidence of child wasting, stunting and underweight. Based on a qualitative research, Alemu et al. (2005a) noted that service quality, availability of drugs and affordability of health services have a greater impact on a child's nutritional status than distance to health services.

On the other hand, Alemu et al. (2005b) found distance to a public health clinic to have the expected negative and significant association with weight-for-height in rural areas, but the result is the opposite for urban areas, which is not expected.

Some studies use the number of prenatal care visits of a mother as proxy for access to health services and they found it to be significant for children of lower age group i.e between 0 and 12 months old. For example, Woldemariam and Timotiwos (2002) found that the odds of stunting among children whose mothers have had no or (1-4) prenatal care visits were 1.5 times more compared with children whose mothers had five or more prenatal care visits. The authors argue that this is because as the contact of mothers with health services increases, their health seeking behaviour improves and therefore they are likely to take appropriate actions to improve the health status of their children, which is also important component of child nutrition.

Using antenatal visits and child vaccinations against measles as proxies for health-seeking behaviour, Alemu et al. (2005a) found children less likely to be wasted and underweight suggesting the importance of the use of health facilities/services in reducing the incidence of underweight and wasting. However, from the qualitative research these authors found that there is still both inadequate understanding of and/or trust in modern scientific healthcare in tackling malnutrition, which is in turn reflected in an unwillingness to replace reliance on spiritual healers with faith in modern medicine.

Chapter Three

Data and Methodology

3.1 Data

This research utilizes the Ethiopia 2005 Demographic and Health Survey as its source of data that is the second comprehensive and nationally representative population and health survey. An important feature of the data set is that it avails in-depth information on demographic and health aspects of households. Information regarding fertility and family planning behaviour, child mortality, nutritional status of children, utilization of maternal and child health services, and knowledge of HIV/AIDS and sexually transmitted diseases (STDs) is available from the data set.

The 2005 Ethiopian Demographic and Health Survey (EDHS) is designed to provide estimates for the health and demographic variables of interest for the following domains: Ethiopia as a whole; urban and rural areas of Ethiopia (each as a separate domain); and 11 geographic areas (9 regions and 2 city administrations).

In general, the DHS sample is stratified, clustered and selected in two stages. In the 2005 EDHS a representative sample of approximately 14,500 households from 540 clusters was selected. In the first stage, 540 clusters (145 urban and 395 rural) were selected from the list of enumeration areas based on the 1994 Population and Housing Census sample frame. A total of 5,280 children less than 59 months were identified in the households of selected clusters.

From 5,280 children aged less than 59 months only 3108 are measured for anthropometric measurements height and weight. Thus, the analysis presented in this study on health/nutritional status is based on the 3108 children aged less than 59 months with complete anthropometric measurements.

3.2 Variables included in the study

As demonstrated in the literature review, socio-economic, demographic, health and environmental characteristics are considered as the most important determinants of child nutrition and health status.

a. The Response variable

Height-for-age, weight-for-height and weight-for-age Z-scores which give the information about stunting, wasting and underweighting are used as measure of health outcomes, respectively.

In this study, height and weight measurements of children, taking age into consideration, were converted into Z-scores based on the National Center for Health Statistics (NCHS) reference population recommended by the World Health Organization (WHO). Thus, those below -2 standard deviations of the NCHS median reference for height-for-age, weight-for-age and weight-for-height are defined as stunted, underweighted, and wasted, respectively. All the three indicators are used to describe the level of child malnutrition/health problem. But wasting represents a short-term indicator useful only to monitor short-term changes in nutritional status. Therefore, an in-depth analysis was performed on stunting and underweight.

b. Explanatory variables

The predictor variables, to be studied as determinants of nutrition and health status of children, are grouped in to socio-economic, demographic, and health and environmental factors.

i. Socio-Economic Characteristics

As proxy indicators of socioeconomic characteristics the following factors are included: mother’s education, employment status of the mother, employment status of partner, education of partner, household income, household size, place of residence and region.

ii. Demographic Characteristics

Demographic characteristics include age of the child, sex of the child, sex of household head and birth order.

iii. Health and Environmental Characteristics

There are certain health and environmental characteristics that may increase or decrease the risk of malnutrition and health problem among children. Diarrhea, fever, water supplies and toilet facilities are important health and environmental factors included in this study.

C. Description of Variables included in the Analysis

- **Response Variable**

Variable	Definition of variable	Representation of variable
Stunting	Height-for-age Z-scores	Y_1
Underweight	Weight-for-age Z-scores	Y_2

- **Predictor Variables**

1) Socio- economic Variables

Variables	Categories
Mother's Education(Medu)	(0) No education (1) Primary education, (2) Secondary and above
Employment status of mother (Memploy)	(0) Unemployed (1) Employed
Employment status of partner (Pemploy)	(0) Agricultural (1) Non-agricultural
Wealth index(Windex)	(0) Poor (1) Medium (2) Rich
Education of partner (Pedu)	(0) No education (1) Primary education (2) Secondary and above
Number of household member (HHmem)	(0) 1-4 (1) 5-9 (2) 10 and above
Place of Residence (Plread)	(0) Rural (1) Urban
geographical region (REGION)	(0) Tigray (1) Afar (2) Amhara (3) Oromia (4) Somali (5) Ben-gumuz (6) SNNP (7) Gambela (8) Harari (9) Addis Ababa (10) Dire Dawa

2) Demographic Variables

Variables	Categories
Sex of child (Sexoch)	(0) Female (1) Male
Sex of household head(Sexohd)	(0) Male (1) Female
Age of child (Aochild)	(0) <6 months (1) 6-11 months (2) 12-23 months (3) 24-35 months (4) 36-47 months (5) 48-59 months
Birth order of the child (BORD)	(0) 1 (1) 2-3 (2) 4-5 (3) 6+

3) Health and Environmental Characteristics

Variables	Categories
Had diahrea in the two weeks before survey (Diarrhea)	(0) No (1) Yes
Had fever in the two weeks before survey (Fever)	(0) No (1) Yes
Source of water supply (Water)	(0) Surface water (1) Pipe water (2) Open well water
Type of toilet facility (Toilot)	(0) Have facilities (bush, field) (1) No facilities (Pit toilet, Flush toilet

3.3 Methodology

We build our methodology in three stages depending on our objectives. First, we ignore the hierarchical structure of the data and the possibility that some correlation may exist across the stunting and underweight. Treating the geographical region as unit of analysis, we estimate a multiple linear regression model separately for each response variables, allowing for the possibility that variation in nutrition and health status might be attributable to differences in population demography, socio-economic and health and environmental condition. Second, recognising the 'the children within region' hierarchical structure to the data, we separately identify a regional effect from a child-level effect on nutrition and health status of children by using univariate multilevel linear regression model. Finally, recognising the 'the children within region' hierarchical structure to the data, the association between measure of nutrition and health status (response variables) and the joint analysis of the effects of explanatory variables on the associated response variables are acknowledged and investigated by using a multivariate multilevel linear regression analysis.

3.3.1 Introduction to linear regression analysis

Regression analysis is a statistical tool for the investigation of relationships between one or multiple independent variables and single or more continuous dependent variables.

Multiple Linear regression model is a general statistical model that is used when there are one or multiple independent variables and a single continuous dependent variable. It assumes that the response variable is a linear function of the model parameters. Under this study, to ascertain the effect of explanatory variables upon the response variables separately, to estimate the quantitative effect of the explanatory variables upon the variable that they influence and to assess the "statistical significance" of the estimated relationships, we employ univariate linear regression analysis. The following is the necessary notation and specify the multiple linear regression model in this study.

Let y_i, i=1,2,. . ., n represent the response variable of the i^{th} individual , x_{pi},p=1,2, . . ., P is the p covariates included in the analysis measured at individual (child) i, β_p,p=0,1,2, . . ., P regression coefficients and ε_i is a residual term, assumed to have mean zero and constant variance σ^2 .Then the univariate linear regression model is compactly written as

$$y_i = \beta_0 + \sum_{p=1}^{P} \beta_p x_{pi} + \varepsilon_i \qquad (3.1)$$

To use the model for prediction further analysis regarding model adequacy are required. Therefore, it is usual practice that after fitting the model the next step is to check the model adequacy. Checking model adequacy is equivalent to checking the validity of the model assumptions, examine the presence of outliers and influential variables. This can be carried out through residual analysis and by employing some statistical techniques.

The maximum likelihood (ML) and ordinary least squares (OLS) are the two most competing estimation methods used in fitting linear regression model. In this study, we employ the maximum likelihood estimation techniques using MLwiN software.

The significance of individual regression coefficients (H_0: $\hat{\beta}_p = 0$ Vs H_1: $\beta_p \neq 0$ p = 0, 1, 2, …, P) can be tested by using the test statistic $T(\beta) = \frac{\hat{\beta}_p}{S.E\left(\hat{\beta}_p\right)}$, has a student's t-distribution with n-p-1 degree of freedom when H_0 is true. For large samples $T(\hat{\beta})$ has an approximate N (0, 1) distribution if H_0 is true.

A variety of statistical tests exist for determining the significance or goodness-of-fit of a multiple linear regression model. Some of these measures are: Likelihood Ratio Test; and Nagelkerke Pseudo R^2 (Greene, 2003). In this study we employ likelihood ratio test for a goodness of-fit assessment of the model and for testing the overall significance of a multiple regression

3.3.2 Introduction to Multilevel Analysis

The basic idea of multilevel analysis is that data sets with a nesting structure that includes unexplained variability at each level of nesting are usually not adequately represented by multiple regression. The reason is that the unexplained variability in single-level multiple regression analysis is only the variance of the residual term. Variability in multilevel data, however, has a more complicated structure related to the fact that several populations are involved in modeling such data: one population for each level. Explaining variability in a multilevel structure can be achieved by explaining variability between level-1 units but also by explaining variability between higher-level units (Snijders and Bosker, 1999).

Multilevel analysis is a methodology for the analysis of data with complex patterns of variability, with a focus on nested sources of variability. These are used when the data structure is hierarchical with elementary units at level 1 nested in clusters at level 2, which in turn may be nested in (super) clusters at level 3, and so on. The latent variables, or random effects, are interpreted as unobserved heterogeneity at the different levels which induce dependence among all lower-level units belonging to a higher-level unit. Random intercepts represent heterogeneity between clusters in the overall response and random coefficients represent heterogeneity in the relationship between the response and explanatory variables.

The best approach to the analysis of multilevel data is an approach that represents within-group as well as between-group relations within a single analysis, where 'group' refers to the units at the higher levels of the nesting hierarchy (Snijders and Bosker, 1999).

3.3.2.1 Heterogeneous Proportion

For the proper application of multilevel analysis the first logical step is to test heterogeneity of proportions between the groups. To test whether there are indeed systematic differences between the groups, one can use the exact test for the hypothesis that the intra-class correlation is zero, which is the same as the null hypothesis that there are no group differences, or the true between-group variance is zero. The test statistic for this purpose is given as:

$$F = \frac{\tilde{n} \times S^2_{between}}{S^2_{within}} \quad \text{(Snijders and Bosker, 1999)} \qquad 3.2$$

and it has an F distribution with N-1 and M-N degree of freedom if the null hypothesis holds, and

N=the number of level two units

$M = \sum_j n_j$ =the total sample size

$$\tilde{n} = \frac{1}{N-1}\left\{ M - \frac{\sum_j n_j^2}{M} \right\}$$

$$S^2_{within} = \frac{1}{M-N}\sum_{j=1}^{N}\sum_{i=1}^{n_j}(Y_{ij} - \bar{Y}_{.j})^2 = \frac{1}{M-N}\sum_{j=1}^{N}(n_j - 1)S_j^2$$

$$S_j^2 = \frac{1}{n_j - 1}\sum (Y_{ij} - \bar{Y}_{.j})^2$$

$$S_{between}^2 = \frac{1}{N - 1}\sum (\bar{Y}_{.j} - \bar{Y}_{..})^2$$

$$\bar{Y}_{.j} = \frac{1}{n_j}\sum_{i=1}^{nj} Y_{ij}$$

$$\bar{Y}_{..} = \frac{1}{M}\sum_{j=1}^{N}\sum_{i=1}^{n_j} Y_{ij} = \frac{1}{M}\sum n_j \bar{Y}_{.j}$$

3.3.2.2 Univariate multilevel linear regression

In the univariate case we are interested in a single response variable measured at each occasion for each individual. In this study, the clustering of the data points within geographical regions offers a natural 2-level hierarchical structure of the data, i.e. children are nested within regions. The following is the necessary notation to specify the univariate multilevel regression model in this study.

Let y_{ij} represent the measure of the response variable y for individual i at group j. Index j=1,2,…,N denotes higher level units(groups) and index i=1,2,….,N_j denotes the measures of children at group j. Let $x_{p,ij}$, p=1,2,…, P, denotes the P covariates included in the analysis, as measured at children i belonging to group j. β_{oj} is assumed to vary randomly and given by the sum of an average intercept β_0 and group dependent deviations U_{0j} (assumed mutually independent and normally distributed with mean zero and variance σ_0^2), that is, $\beta_{0j} = \beta_0 + U_{0j}$, β_p, p=1, 2,…, P, denotes slope coefficients and ε_{ij} is a residual term, assumed to have mean zero and variance σ_ε^2 Then we may have the following types of models:

a) Intercept-only Model: This is the simplest case of hierarchical linear model in which there are no explanatory variables at all. This model only contains random groups and random variation within groups. It can be expressed as a model where the dependent variable is the sum of a general mean, β_0, a random effect at the group level, U_{0j}, and a random effect at individual level, ε_{ij}: i.e.,

$$\begin{aligned} y_{ij} &= \beta_{0\mathrm{j}} + \varepsilon_{ij} \\ &= \beta_{o} + U_{oj} + \varepsilon_{ij} \end{aligned} \tag{3.3}$$

This model is useful because it gives us an estimate of intra-group correlation.

$\rho(y_{ij}, y_{i'j}) = \rho = \dfrac{\sigma^2{}_0}{\sigma^2{}_0 + \sigma^2{}_\varepsilon}, i \neq i'$ -------------- (3.4) which is referred to as intra-group correlation.

For intercept-only model $E(y_{ij}) = \beta_0$ *and* $Var(y_{ij}) = Var(\mu_{0j}) + Var(\varepsilon_{ij}) = \sigma_0^2 + \sigma_\varepsilon^2$.

$Cov(y_{ij}, y_{i'j}) = Var(U_{0j}) = \sigma^2{}_0$ (The covariance between two individuals ($i \neq i'$) in the same group j).

This correlation measures the proportion of the total variance which is between-groups. The intercept-only model also gives us the value of the deviance, which is a measure of the degree of miss-fit of the model (McCullagh and Nelder, 1989)

b) Random intercept model: This is a model in which all lower level explanatory variables are fixed. This means that the corresponding variance components of the slope are fixed at zero. It is used to assess the contribution of each individual explanatory variable.

$$y_{ij} = \beta_0 + \sum_{p=1}^{P} \beta_p x_{pij} + U_{0\mathrm{j}} + \varepsilon_{ij} \tag{3.5}$$

Note that the first part $\beta_0 + \sum_{p=1}^{P} \beta_p x_{pij}$ is the fixed part of the model, because the coefficients are fixed. The remaining part $U_{0\mathrm{j}} + \varepsilon_{ij}$ is called the random part of the model.

c) The Random Coefficients Model: This is used to assess whether the slope of any of the explanatory variables has a significant variance component between the groups.

$$y_{ij} = \beta_0 + \sum_{p=1}^{P} \beta_p X_{pij} + U_{0\mathrm{j}} + \sum_{p=1}^{P} U_{pj} X_{pij} + \varepsilon_{ij} \tag{3.6}$$

The first part, $\beta_0 + \sum_{p=1}^{P} \beta_p X_{pij}$, is called the fixed part of the model and the second part,

$U_{0\mathrm{j}} + \sum_{p=1}^{P} U_{pj} X_{pij} + \varepsilon_{ij}$ is called the random part. The term $\sum_{p=1}^{P} U_{\mathrm{pj}} x_{1ij}$ can be regarded as a random interaction between group and the explanatory variables.

This model implies that the groups are characterized by two random effects: their intercept and their slopes. It assumes that, for different groups, the pairs of random effects $(U_{oj}, U_{pj}, p = 1{,}2..., P)$ are independent and identically distributed, that they are independent of the level-1 residuals, ε_{ij}, and that all ε_{ij} are independent and identically distributed.

3.3.2.3 Multivariate Multilevel linear regression

The multilevel model described above is calibrated separately for each measure of nutrition and health status. The multilevel framework can be extended to consider multiple outcomes simply by recognizing that the measure of nutrition and health status themselves are clustered within children. This is a multivariate model in a multilevel context.

Multivariate response data are conveniently incorporated into a multilevel model by creating an extra level “below” the original level 1 units to define the multivariate structure. We thus have responses within individuals that are in turn nested within higher-level units.

Multivariate Multilevel (MVML) analysis is a methodology for the analysis of more than one response variables of data manifesting complex patterns of variability, with a focus on nested sources of variability. This statistical specification allows the joint analysis of the effects of explanatory variables on the associated response variables and estimates any residual correlation between outcomes. It also allows for comparisons and joint significance test of the fixed effects of the same explanatory variable on more than one response variable (Snijders and Bosker 1999).

In this study, the clustering of the data points within geographical regions offers a natural 2-level hierarchical structure of the data, i.e. children are nested within regions. To explore the associations of health and nutrition status in various forms, a third-level reflects the multivariate structure of the model. Thus health and nutrition status may be associated in a twofold manner: indirectly, via jointly significant fixed effects of common explanatory variables and controls (as estimated in the fixed part of the model), and intrinsically, via residual (unexplained or unobserved) covariance, which is captured in the random parameters at each level.

The following is the necessary notation and specifies the MVML regression model in this study.

Let Y_{ijk} , i=1, 2, indicate the two response variables of interest where Y_{1jk} and Y_{2jk} denote health and nutrition status of stunting and underweight, respectively. Index k=1,2,…,N denotes the region (level-3) and index j=1,2,…., N_k denotes children at region k and N_k is the total number of children per region in the sample. That is Y_{ijk} is the observed value of the i^{th} response variable of child j that belongs to region k.

Let $x_{p,jk}$, p=1, 2,…, P, denotes the P covariates that will be included in the analysis, as measured at children j belonging to the highest level k. β_{oi} is the non-random intercept of the regression equation for the i^{th} response variable, β_{pi}, p=1, 2,…, P denotes slope coefficients and ε_{oi} is a random part for each response variable i consisting of additive random contribution from hierarchical levels, $\varepsilon_{oi} = u_{ijk} + v_{ik}$

Here u_{ijk} is an inter-children random effect capturing level-2 variation, v_{ik} is an inter-group random effect capturing level-3 variation. The lower level for response variable i simply defines the multivariate structure and does not contribute any extra random variation to the regression model.

If we let $z_{sijk} = \begin{cases} 0, s \neq i \\ 1, s = i \end{cases}$ s, i =1, 2 denote a dummy variable assuming the value 1 when s=i and 0 otherwise, then MVML model is compactly written as:

a. Multivariate empty model: Model with no explanatory variable at all:

$$Y_{ijk} = \sum_{s=1}^{2} z_{sijk}\left[\beta_{os} + u_{sjk} + v_{sk}\right]$$

$$= \sum_{s=1}^{2} z_{sijk}\beta_{os} + \sum_{s=1}^{2} z_{sijk}u_{sjk} + \sum_{s}^{2} z_{sijk}v_{sk} \tag{3.7}$$

b. Multivariate random intercept model

$$Y_{ijk} = \sum_{s=1}^{2} z_{sijk}\left[\beta_{os} + \sum_{p=1}^{P}\beta_{ps}x_{pjk} + u_{sjk} + v_{sk}\right]$$

$$= \sum_{s=1}^{2} z_{sijk}\beta_{os} + \sum_{s=1}^{2}\sum_{p=1}^{P} z_{sijk}\beta_{ps}x_{pjk} + \sum_{s=1}^{2} z_{sijk}u_{sjk} + \sum_{s=1}^{2} z_{sijk}v_{sk} \qquad (3.8)$$

c. Multivariate random slope model

$$Y_{ijk} = \sum_{s=1}^{2} z_{sijk}\left[\beta_{os} + \sum_{p=1}^{P}\beta_{ps}x_{pjk} + \sum_{p=1}^{P}u_{psjk}x_{pjk} + u_{sjk} + v_{sk}\right]$$

$$= \sum_{s=1}^{2} z_{sijk}\beta_{os} + \sum_{s=1}^{2}\sum_{p=1}^{P} z_{sijk}\beta_{ps}x_{pjk} + \sum_{s=1}^{2} z_{sijk}u_{sjk} + \sum_{s=1}^{2}\sum_{p=1}^{P} z_{sijk}u_{pjk}x_{pjk} + \sum_{s=1}^{2} z_{sijk}v_{sk} \qquad (3.9)$$

Each one of these random effects is assumed to follow a convenient multivariate normal distribution as defined below

$(u_{1jk}, u_{2jk})^T \sim MVN(0, \Omega_u)$, where $\Omega_u = \text{cov}(u_{sjk})$

$\{\Omega_u\}_{si} = \text{cov}(u_{sjk}, u_{ijk}) = \sigma_{usi}, s \neq i$, $\text{cov}(u_{ijk}, u_{ijk}) = \sigma^2{}_{ui}$,

$(v_{1k}, v_{2k})^T \sim MVN(0, \Omega_v)$, where $\Omega_v = \text{cov}(v_{sk})$ $\{\Omega_v\}_{si} = \text{cov}(v_{sk}, v_{ik}) = \sigma_{vsi}$, $i \neq s$, $\text{cov}(v_{ik}, v_{ik}) = \sigma^2{}_{vi}$

Effectively, z_{ijk} values are such that only relevant terms are retained in any of the models. $\sigma^2{}_{ui}$ is the between children unexplained variance of the i^{th} response variable while σ_{usi} is the between children unexplained covariance between the s^{th} and i^{th} responses. $\sigma^2{}_{vi}$ is the between-group unexplained variance of the i^{th} response variable while σ_{vsi} is the between-group unexplained covariance between the s^{th} and i^{th} responses.

The total residual covariance matrix is $\text{cov}(Y_{ijk}) = \text{cov}(u_{sjk}) + \text{cov}(v_{sk}) = \Omega_u + \Omega_v$

The correlation coefficients are given by:

$\rho(v_{sk}, v_{ik}) = \rho_v = \dfrac{\sigma_{vsi}}{\sqrt{(\sigma_{vi}^2 + \sigma_{vs}^2)}}$ is correlation between stunting and underweight at level-3.

$\rho(u_{sjk}, u_{ijk}) = \rho_u = \dfrac{\sigma_{usi}}{\sqrt{(\sigma_{ui}^2 + \sigma_{us}^2)}}$ is correlation between stunting and underweight at child level.

$\rho(Y_{ijk}, Y_{sjk}) = \rho_Y = \dfrac{\Omega_u + \Omega_v}{\sqrt{((\sigma_{vi}^2 + \sigma_{ui}^2) + (\sigma_{vs}^2 + \sigma_{us}^2))}}$ is correlation between observed variables.

$\rho(Y_{ijk}, Y_{ij'k}) = \dfrac{\sigma_{\mathrm{vi}}^2}{\sigma_{\mathrm{vi}}^2 + \sigma_{\mathrm{ui}}^2}$, is the intra-group correlation coefficient or the fraction of total variability that is due to group (Snijders and Bosker, 1999)

3.3.2.4 Diagnostic Checks for Multilevel Models

Multilevel linear regression analysis like other regression models is based on several assumptions, and inspection of the residuals can be used to examine the assumptions. One important difference from ordinary regression analysis is that we have more than one residual. Consequently, many different residual plots can be used (J.Hox, 2002).

3.3.2.5 Estimation Techniques

The statistical theory behind the multilevel regression model is complex. On the basis of the observed data, we want to estimate the parameters of the multilevel regression model: the regression coefficients and the variance components. The estimators currently used in multilevel regression analysis are maximum likelihood (ML) estimators. ML estimators estimate the parameters of a model by providing estimates for the population values that maximize the so-called likelihood function: the function that gives the probability of observing the sample data, given the current parameter estimates.

Various algorithms are available to determine these estimates. They have names such as EM (Expectation-maximization), Fisher scoring, IGLS (Iterative Generalized Least Squares), and RIGLS (residual or restricted IGLS). They are iterative, which means that a number of steps is taken in which provisional estimates come closer and closer to the final estimate. When all goes well, the steps converge to the ML estimate. Technical details can be found, e.g., in Bryk and Raudenbush (1992), Goldstein (1995), or Longford (1993a, 1995).

In this study, the estimation will be done usig IGLS algorithms (techniques) using the software MLwiN.

3.3.2.6 Testing the significance of parameters

a. Test for fixed parameters

Maximum likelihood procedures produce standard errors for most of the estimates. The standard errors can be used for significance testing.

The null hypothesis that a certain regression parameter is 0, i.e.,

$H_0 : \beta_p = 0,$ Vs $H_1 : \beta_p \neq 0,$ p=1, 2,. . . ,P, can be tested by a t-test using the test statistic $T(\hat{\beta}_p) = \dfrac{\hat{\beta}_p}{S.E\left(\hat{\beta}_p\right)}$

Under the null hypothesis, $T(\hat{\beta}_p)$ has approximately a t-distribution with the number of degree of freedom (d.f.) =M-r-1 where M is the total number of observations and r is total number of explanatory variables. If M-r is large enough, say, larger than 40, the t-distribution can be replaced by a standard normal distribution (Snijders and Bosker, 1999).

b. Deviance test (likelihood ratio test)

The deviance-based test, or likelihood ratio test, is a general principle for statistical testing. In applications of a hierarchical linear model, this test is mainly used for multi-parameter tests and for tests about the random part of the model. The general principle is as follows.

When parameters of a statistical model are estimated by the maximum likelihood (ML) method, the estimation also provides the likelihood, which can be transformed into the deviance defined as minus twice the natural logarithm of the likelihood.

Suppose that two models are fitted to one data set, model M_0 with m_0 parameters and a large model M_1 with m_1 parameters. So M_1 can be regarded as an extension of M_0, with (m_1-m_0)

parameters added. Suppose that M_0 is tested as the null hypothesis and M_1 is the alternative hypothesis. Indicating the deviances by D_0 and D_1, respectively, their difference D_0-D_1 can be used as a test statistic having a Chi-Square distribution with (m_1-m_0) degrees of freedom.

3.3.2.7 Goodness of fit test

The maximum likelihood procedure produces a statistic called the deviance, which indicates how well the model fits the data. This deviance can regarded as a measure of fit between the model and data, but (in most statistical models) cannot interpret the value of the deviance directly but only differences in deviance values for several models fitted to the same data set (Snijders and Bosker, 1999). That means, if the two models are nested (which means that a specific model can be derived from a more general model by removing parameters from the general model) the difference of the deviances for the two models has a chi-square distribution with degree of freedom equal to the difference in the number of the parameters estimated in the two models. This can used to perform a formal chi-square test to test whether the more general model fits significantly better than the simpler model.

CHAPTER FOUR

STATISTICAL DATA ANALYSIS

4.1 Major demographic, socioeconomic, and health and environmental characteristics with measures of health and nutritional status of children

In this study, we have examined the measures of health / nutritional status of children as it varies with demographic, socio-economic, and health and environmental characteristics. The total number of children covered in the present study is 3108. Among these, 2756 (88.7%) reside in rural areas whereas 352 (11.3%) reside in urban centers. In terms of gender, about 50.7 percent of the children are males.

In the discussion of child health and nutrition using anthropometric outcomes, the first step is usually to look at the distribution of the z-scores. As discussed in Chapter 2, the cut-off point to define abnormal anthropometry with Z- scores is -2 standard deviations. A more general rule of thumb for evaluating anthropometric Z-scores has been developed by WHO, with a score of less than -3 indicating “severe” malnutrition, between -3 and -2.01 “moderate” malnutrition, -2 to -1.01 “mild” malnutrition and -1 and above considered normal.

4.1a Major demographic, socioeconomic, and health and environmental characteristics with underweight (W/A z-scores)

The major socioeconomic, demographic, health and environmental background characteristics of the respondents and children with underweight are presented in Table 4.1a below. Out of 3108 children covered in this study, 1245 (40.1 percent) are found to be underweight whereas 1863 (59.9 percent) are not underweight.

Table 4.1a Distribution of socioeconomic, demographic, and health and environmental related characteristics and W/A z-score.

		W/A z-score		
		underweight		Total
		Number of underweight children	Percent	Number of children
Place of residence	Rural	1179	42.8%	2756
	Urban	66	18.8%	352
Region	Tigray	168	45.8%	367
	Afar	67	41.1%	163
	Amhara	224	50.5%	444
	Oromiya	234	37.5%	624
	Somali	99	52.4%	189
	Ben-Gumz	114	44.2%	258
	SNNP	195	34.9%	558
	Gambela	36	30.3%	119
	Harari	59	34.1%	173
	Addis Ababa	16	16.5%	97
	Dire Dawa	33	28.4%	116
Educational status of mothers	No education	1053	43.4%	2427
	Primary	168	32.6%	515
	Secondary and above	24	14.5%	166
Educational status of mothers' partner	No education	837	44.8%	1870
	Primary	331	36.9%	896
	Secondary and above	77	22.5%	342
Wealth index	poor	867	44.0%	1972
	Medium	317	38.0%	834
	Rich	61	20.2%	302
Employment status of mothers	Unemployed	848	39.3%	2160
	Employed	397	41.9%	948
Employment status of mothers' partner	Agricultural	1131	43.6%	2597
	non agricultural	114	22.3%	511
Age of child	<6 months	17	6.9%	245
	6-11 months	81	31.6%	256
	12-23 months	290	47.9%	605
	24-35 months	268	43.8%	612
	36-47 months	286	40.2%	712
	48-59 months	303	44.7%	678
Birth order of children	1	163	32.7%	498
	2-3	369	37.8%	976
	4-5	339	44.0%	771
	6+	374	43.3%	863
Number of household member	1-4	260	37.2%	699
	5-9	910	41.1%	2214
	10+	75	38.5%	195
Sex of child	Female	599	39.1%	1531
	Male	646	41.0%	1577
Sex of household head	Female	156	39.5%	395
	Male	1089	40.1%	2713
Type of drinking water	Surface water	902	43.7%	2062
	Piped water	178	28.4%	626
	Open well water	165	39.3%	420
Toilet facilities	No facilities	105	40.5%	259
	have facilities	1140	40.0%	2849
Diarrhea	No	978	38.6%	2532
	yes	267	46.4%	576
Fever	NO	1023	40.1%	2551
	Yes	222	39.9%	557

The proportion of underweight children, as can be seen in Table 4.1a, differs by type of place of residence: urban and rural. Accordingly, higher numbers of underweight children (42.8 percent) reside in rural areas, and relatively small numbers of underweight children (18.8 percent) reside in urban centers.

Moreover, the health/nutritional status of children varied from one region to the other. For example, the highest prevalence of child-underweight was observed in Somali(52.4) followed by Amhara (50.5 percent) as opposed to the lowest prevalence which was recorded in Addis Ababa (16.5 percent) and followed by Dire Dawa (28.4 percent).

Likewise, as Table (4.1a) shows, the health/nutritional status of children varies by educational status of mothers. The highest prevalence of child-underweight was observed from children whose mothers have no education (43.4 percent) as opposed to the lowest prevalence of child-underweight which was recorded from children whose mothers have secondary and above education level (14.5 percent).

Regarding mothers' partners educational status, the highest prevalence of child-underweight was observed among children whose mothers' partners have no education (44.8 percent) as opposed to the lowest prevalence of child-underweight which was recorded from children whose mothers' partners have secondary and above education level (22.5 percent).

Table (4.1a) also shows that the proportion of health/nutritional status of children varies by households' economic status. The highest prevalence of underweight was observed among children from poor households (44.0percent) as opposed to the lowest prevalence of child-underweight which was recorded from children residing in rich households (20.2 percent).

Regarding mothers' partners employment status, those working in the agricultural sector show higher prevalence of child underweight (43.6 percent) than those in the non-agricultural sector (22.3 percent). With regards to child age, the highest proportion of underweight children were observed among those whose age group is 12-23 months (47.9 percent) as opposed to the smallest percentage (6.9 percent) of underweight children which was observed among those whose age group is less than 6 months.

4.1b Major demographic, socioeconomic, and health and environmental characteristics with stunting (H/A z-scores)

The major socioeconomic, demographic, health and environmental background characteristics of the respondents and children with stunting are presented in Table 4.1b below. The total number of children who are measured for anthropometric measurements of height for age is 3108. Among these, 1426 (45.9 percent) were found to be stunted whereas 1682 (54.1 percent) were not stunted.

Table 4.1b Distribution of socioeconomic, demographic, and health and environmental related characteristics and stunting

		stunting		
		stunted		Total
		Number of stunted children	Percent	Number of children
Place of residence	Rural	1339	48.6%	2756
	Urban	87	24.7%	352
Region	Tigray	162	44.1%	367
	Afar	72	44.2%	163
	Amhara	266	59.9%	444
	Oromiya	285	45.7%	624
	Somali	86	45.5%	189
	Ben-Gumz	105	40.7%	258
	SNNP	284	50.9%	558
	Gambela	41	34.5%	119
	Harari	71	41.0%	173
	Addis Ababa	19	19.6%	97
	Dire Dawa	35	30.2%	116
Educational status of mothers	No education	1185	48.8%	2427
	Primary	201	39.0%	515
	Secondary and above	40	24.1%	166
Educational status of mothers' partner	No education	926	49.5%	1870
	Primary	407	45.4%	896
	Secondary and above	93	27.2%	342
Wealth index	Poor	977	49.5%	1972
	Medium	372	44.6%	834
	Rich	77	25.5%	302
Employment status of mothers	Unemployed	969	44.9%	2160
	Employed	457	48.2%	948
Employment status of mothers' partner	Agricultural	1267	48.8%	2597
	Non agricultural	159	31.1%	511
Age of child	<6 months	25	10.2%	245
	6-11 months	77	30.1%	256
	12-23 months	319	52.7%	605
	24-35 months	299	48.9%	612
	36-47 months	346	48.6%	712
	48-59 months	360	53.1%	678
Birth order of children	1	192	38.6%	498
	2-3	435	44.6%	976
	4-5	370	48.0%	771
	6+	429	49.7%	863
Number of household members	1-4	293	41.9%	699
	5-9	1052	47.5%	2214
	10+	81	41.5%	195
Sex of child	Female	689	45.0%	1531
	Male	737	46.7%	1577
Sex of household head	Female	166	42.0%	395
	Male	1260	46.4%	2713
Type of drinking water	Surface water	1028	49.9%	2062
	Piped water	214	34.2%	626
	Open well water	184	43.8%	420
Toilet facilities	No facilities	125	48.3%	259
	have facilities	1301	45.7%	2849
Diarrhea	No	1139	45.0%	2532
	Yes	287	49.8%	576
Fever	NO	1175	46.1%	2551
	Yes	251	45.1%	557

The proportion of stunted children, as can be seen in Table 4.1b, differs by type of place of residence: urban and rural. Accordingly, nearly half of the stunted children (48.6 percent) reside in rural areas unlike the relatively smaller number of stunted children (24.7 percent) who reside in urban centers

Moreover, the health/nutritional status of children varied from one region to the other. For example, the highest prevalence of child-stunting was observed in Amhara (59.9 percent) followed by SNNP (50.9percent) as opposed to the lowest prevalence which was recorded in Addis Ababa (19.6 percent) and followed by Dire Dawa (30.2 percent).

Likewise, as Table 4.1b shows, the health/nutritional status of children varied by educational status of mothers. The highest prevalence of child-stunting was observed from children whose mothers have no education (48.8 percent) as opposed to the lowest prevalence of child stunting which was recorded from children whose mothers have secondary and above education level (24.1 percent).

Table 4.1b also shows that the proportion of health/nutritional status of children varies by the households' economic status. The highest prevalence of stunting was observed among children from poor households (49.5 percent) as opposed to the lowest prevalence of child stunting which was recorded from children residing in rich households.

With regards to child age, the highest proportion of stunted children was observed among those whose age group is 48-59 months (53.1 percent) as opposed to the smallest percentage (10.2 percent) of stunted children which was observed among those whose age group is less than 6 months.

4.2 Determinant of health/ nutrition status of children: Univariate Linear Regression Analysis

Multiple linear regression analysis is used to examine the effect of each independent variable in the model on health/nutrition status of children while controlling for the other independent variables. Thus, two different models are fitted in this study to see the basic determinants of health/nutrition status among children aged less than 59 months at the national level as discussed in Section 3.3.1. The first model is fitted to identify the basic demographic, socio-economic, and health and environmental determinants of health/nutrition status of children in terms of short and long-run measures of health outcomes (underweight) at the national level. Similarly, the second model is fitted to identify the determinants of health/nutrition status of children in terms of long-run measures (stunting) at the national level.

4.2a Goodness Of fit test

Goodness of fit of the fitted multiple linear regression models was assessed using deviance-based chi-square test. Accordingly, the deviance-based chi-square test provided chi-square value of 720.047 ($p<0.001$) and 611.66 ($p<0.001$) which would imply good fit for the underweight and stunting models, respectively.

4.2b. Model diagnosis

The fitted model was checked for possible presence of outliers and influential values and also for homoscedasticity and normality of the residuals. The diagnostic test results for detection of outliers and influential values, test of homoscedasticity and normality are presented in Appendix A.

Thus, from the goodness of fit test and diagnostic test results presented in the Appendix A, we can say that our model is adequate.

4.2c. Determinants of health and nutrition status of children in terms of W/A z-scores (underweight) at National level

Multiple linear regression analysis with stepwise variable selection procedure was employed to select the most important determinants of health/nutrition status of children in terms of W/A z-scores**.** The outcome shows that region of residence, employment status of mother, employment status of partners, age of the child, educational status of mothers, educational status of partners, diarrhea and source of drinking water are found to be important predictors of health/nutritional status in terms of underweight.

The results show that the mean W/A z-score for children who reside in the Somali, Amhara, Tigray and Benishangul Gumz region are 0.623, 0.559, 0.489 and 0.467 units less than the mean for children in Addis Ababa, respectively.

The results also show that the mean W/A z-score for children whose mothers are unemployed is 0.077 units more than those children from employed mothers. Concerning partners' employment status, the mean W/A z-score for children whose mothers' partners work in agricultural sectors is 0.232 units less than the mean W/A z-score for children whose mothers' partners are working in non-agricultural sectors. The model also shows that children from mothers with no education and primary education have, on average, about 0.502 and 0.340 units less W/A z-score than children from mothers with secondary and above education level, respectively. Regarding partner's educational status, the mean W/A z-cores for those with no education and primary education are 0.249 and 0.127 units less than the mean for children whose mothers' partners are secondary and above education level, respectively.

The result also shows that the mean W/A z-score for children in the age group less than 6 months and 6-11 months are 1.282 and 0.331 units higher than that for children in the age group 48-59 months, respectively. Concerning sources of drinking water, the mean W/A z-scores for children from households who use surface water is 0.098 units less than the mean for children from households that use piped water. The result also shows that the mean W/A z-score for children who had diarrhea in the two weeks before the survey date is 0.272 units less than that for children who have not.

Table 4.2a Multiple Regression Model results of W/A z-score(underweight) at national level

Covariates	$\hat{\beta}$	$S.E.(\hat{\beta})$	Z_{cal}	p-value
Region				
Tigray	-0.489	0.123	-3.976	0.0000 *
Afar	-0.326	0.134	-2.433	0.0075*
Amhara	-0.559	0.120	-4.658	0.0000*
Oromiya	-0.225	0.118	-1.907	0.0283*
Somali	-0.623	0.113	-5.513	0.0000*
Ben-Gumz	-0.467	0.126	-3.706	0.0001*
SNNP	-0.276	0.118	-2.339	0.0097*
Gambela	-0.106	0.139	-0.763	0.2227
Harari	-0.200	0.129	-1.55	0.0606
Dire Dawa	-0.225	0.139	-1.619	0.0527
Addis Ababa(ref.)				
Memploy				
Unemployed	0.077	0.039	1.974	0.0242*
Employed(ref.)				
Pemploy				
Agricultural	-0.232	0.061	-3.803	0.0000*
Non agricultural(ref.)				
Medu				
No education	-0.502	0.103	-4.874	0.0000*
Primary	-0.340	0.102	-3.333	0.0004*
Secondary and above(ref.)				
Pedu				
No education	-0.249	0.074	-3.365	0.0004*
Primary	-0.127	0.072	-1.764	0.0389*
Secondary and above(ref.)				
Aochild				
<6	1.282	0.072	17.806	0.0000*
6-11	0.331	0.072	4.597	0.0000*
12-23	-0.017	0.055	-0.309	0.3787
24-35	-0.001	0.054	-0.019	0.4924
36-47	0.050	0.052	0.962	0.1680
48-59(ref.)				
water				
Surface water	-0.098	0.053	-1.849	0.0322*
Well water	0.077	0.071	1.085	0.1390
Piped water(ref.)				
Diarrhea				
Yes	-0.272	0.046	-5.913	0.0000*
No(ref.)				
Constant	-0.588	0.112	-5.25	0.0000*

* Significant ($p<0.05$)
ref. = reference category

4.2d Determinants of health and nutrition status of children in terms of H/A z-scores (stunting) at National level

Multiple linear regression analysis with stepwise variable selection procedure is also employed to select the most important determinants of health/nutrition status of children in terms of long-run measures (stunting). The result showed that region of residence, employment status of mother, age of the child, sex of child, household economic level, educational status of partners, employment status of partners, diahrea and source of drinking water are found to be important predictors of health/nutritional status in terms of stunting.

The model indicates that the mean H/A z-score for children who dwell in the Amhara and SSNP region are 0.799 and 0.687 units lower than the mean for children in Addis Ababa, respectively.

Employment status of mothers is also found to be an important determinant of child anthropometric outcomes in terms H/A z-score (stunting). The result shows that the mean of H/A z-scores for children whose mothers are unemployed is 0.093 units higher than that for children from employed mothers. It was also observed that the mean H/A z-scores for children residing in poor households is 2.40 units lower than the mean H/A z-score for children from rich households.

The result also shows that the mean H/A z-score for children in the age group less than 6 months and 6-11 months are 1.842 and 1.062 units higher than the mean of H/A z-score for children in the age group 48-59 months, respectively. As compared with male children, the mean H/A z-score is about 0.11 units higher for female children.

The model also shows that the mean H/A z-score for children who had diarrhea in the two weeks before the survey date is 0.272 units lower than that for the children who had no diarrhea.

Table 4.2b Multiple Regression Model results of H/A z-score (stunting) at national level

Covariates	$\hat{\beta}$	$S.E.(\hat{\beta})$	Z_{cal}	p-value
Region				
Tigray	-0.373	0.179	-2.084	0.0186*
Afar	-0.353	0.195	-1.810	0.0351*
Amhara	-0.799	0.175	-4.566	0.0000*
Oromiya	-0.465	0.171	-2.719	0.0033*
Somali	-0.461	0.193	-2.389	0.0085*
Ben-Gumz	-0.445	0.183	-2.432	0.0075*
SNNP	-0.687	0.172	-3.994	0.0000*
Gambela	-0.208	0.203	-1.025	0.1527
Harari	-0.364	0.186	-4.408	0.0000*
Dire Dawa	-0.037	0.199	-0.186	0.4262
Addis Ababa(ref)				
Memploy				
Unemployed	0.093	0.056	1.661	0.0484*
Employed(ref.)				
Windex				
Poor	-0.240	0.136	-1.765	0.0388*
Medium	-0.168	0.132	-1.273	0.1015
Rich(ref.)				
Pemploy				
Agricultural	-0.144	0.095	-1.516	0.0648
Non agricultural(ref.)				
Medu				
No education	-0.209	0.156	-1.34	0.0901
Primary	-0.062	0.154	-0.403	0.3435
Secondary and above(ref.)				
Pedu				
No education	-0.393	0.106	-3.708	0.0001*
Primary	-0.259	0.103	-2.515	0.0060*
Secondary and above(ref.)				
Aochild				
<6	1.842	0.104	17.712	0.0000*
6-11	1.062	0.103	10.311	0.0000*
12-23	0.167	0.079	2.114	0.0173*
24-35	0.160	0.077	2.078	0.0189*
36-47	0.126	0.074	1.703	0.0443*
48-59(ref.)				
Sexoch				
Female	0.110	0.050	2.200	0.0139*
Male(ref)				
Water				
Surface water	-0.120	0.078	-1.539	0.0619
Well water	0.052	0.103	0.505	0.3068
Piped water(ref.)				
Diarrhea				
Yes	-0.259	0.066	-3.924	0.0000*
No(ref.)				
Constant	-0.878	0.164	-5.354	0.0000*

* Significant ($p<0.05$)

ref. =reference category

4.3 Determinants of health and nutrition status of Children: A Univariate Multilevel Linear Regression Analysis

In the multilevel analysis, a two-level structure is used with regions as the second-level unit and children as the first-level unit. The nesting structure is children within regions that resulted in a set of 11 regions with a total of 3108 children. F-test was applied to assess heterogeneity between regions mean. The test yields F=11.03 (P<0.001) and F=15.99 (P<0.001) for stunting and underweight, respectively. Thus, there is evidence of heterogeneity among the regions with respect to the two measurements of health and nutrition status of children (i.e. stunting and underweight).

4.3.1 Determinants of health and nutrition status of children in terms W/A z-scores at National level

Table 4.3.1 Univariate Multilevel Linear Regression models for underweight and their Deviance based chi-square test

	Empty model	Random intercept model	Random coefficient model
-2loglikelihood	9186.781	8832.320	8789.854
Deviance-based chi-square value	112.781	354.461	42.466
P-value	0.0000*	0.0000*	0.1803

* Significant (p<0.05)

The deviance-based chi-square value for the empty model shown in the above table is the difference in log likelihoods between an empty model for stunting without random effect and an empty model for stunting with random effect (see Appendix B), which is to be compared with the critical value from the chi-squared distribution with 1 degree of freedom. The significance of it implies that an empty model for underweight with random effect is better than an empty model for underweight without random effect.

Likewise, the significant deviance-based chi-square value for random intercept model indicates that the random intercept and fixed slope model is a better fit as compared to the empty model in terms of underweight.

Also the deviance-based chi-square test for significance of random effects for random slope model is statistically insignificant. This implies that as compared to the model with random intercept and fixed slope model, the random intercept and random coefficients model has less fit.

Thus, the deviance-based chi-square test shown in the above table implies that among univariate multilevel linear regression models for underweight, the random intercept and fixed slope model fits significantly better than the others.

4.3.2 Determinants of health and nutrition status of children in terms W/A z-scores (underweight) at National level: Random Intercept and Fixed Slope Linear Regression Model

The results of two-level random intercept and fixed slope (coefficient) model in terms of W/A z-scores (underweight) are presented in table 4.3.1a below.

Results from the fixed part of the model clearly show that the relationship between health/nutritional status of children in terms of underweight and socio-economic, demographic, and health and environmental variables. Hence, employment status of mothers, household economic status, employment status of partners, educational status of mothers, educational status of partners, age of child, birth order of child, sources of drinking water and diahrea are found to be significant determinants of variation in health/nutrition status of children in terms of underweight.

Also the fixed part of the model show that, on average, children from unemployed mothers are less vulnerable to malnutrition and health problems than children from employed mothers in terms of underweight. Likewise, on average, children who live in poor households are highly vulnerable to health problems and malnutrition than children who reside in rich households in terms of underweight.

As table 4.3.1a shows, on average, children whose mothers have no education and primary education level are highly vulnerable to health problem and malnutrition than children whose mothers have secondary and above education level. Table 4.3.1a also portray children in the age group less than 6 months and 6-11 months have better nutrition and health status, on average, than children in the age group 47-59 months in terms of underweight. Similarly, on average children who had diarrhea in the two weeks before the survey date are highly vulnerable to health problem and malnutrition as compared those who have no diarrhea.

As can be seen from the table 4.3.1a below, the variance component representing variation between regions has decreased from 0.086 (see appendix B) in the empty model to 0.023 in the random intercept and fixed slopes multilevel linear regression model and the significance of it indicates that there is a significant variation between regions in the health/nutritional status of children in terms W/A z-scores (underweight).

Table 4.3.2 Random intercept model for underweight at national level

Fixed part	Estimate	S.E	Z_{cal}	p-value
Intercept	-0.828	0.180	-4.6	0.00002*
Plread	0.085	0.106	0.802	0.2113
Urban	-0.026	0.112	0.232	0.4083
Rural(ref.)				
Memploy	-0.097	0.041	-2.366	0.00899*
Unemployed	0.070	0.039	1.842	0.03274*
Employment (ref)				
Windex	0.070	0.038	1.842	0.03274*
Poor	-0.184	0.149	-1.769	0.03845*
Medium	-0.121	0.101	-1.198	0.11546
Rich(ref.)				
Pemploy	0.179	0.080	2.238	0.0126*
Agricultural	-0.191	0.076	-2.513	0.00599*
Non agricultural(ref.)				
Medu	0.193	0.043	4.488	0.00003*
No education	-0.447	0.110	-4.064	0.00002*
Primary	-0.289	0.109	-2.651	0.00401*
Secondary and above(ref.)				
Pedu	0.140	0.033	4.242	0.0001*
No education	-0.243	0.074	-3.284	0.0005*
Primary	-0.132	0.072	-1.833	0.0334*
Secondary and above(ref.)				
HHmem	0.069	0.043	1.605	0.05425
1-4	-0.119	0.088	-1.605	0.05425
5-9	-0.063	0.075	-0.84	0.2005
10+(ref.)				
Aochild	-0.154	0.012	-12.833	0.0000*
<6	1.289	0.073	17.658	0.0000*
6-11	0.347	0.072	4.819	0.0000*
12-23	-0.015	0.055	-0.273	0.3924
24-35	-0.004	0.054	-0.4705	0.3190
36-47	0.052	0.053	0.981	0.1633
48-59(ref.)				
BORD	-0.045	0.021	-2.143	0.0161*
1	0.159	0.065	2.446	0.0072*
2-3	0.033	0.049	0.674	0.2502
4-5	-0.050	0.050	-1.000	0.1687
6+(ref.)				
Sexoch	-0.041	0.036	-1.139	0.1274
Female	0.032	0.035	0.914	0.1804
Male(ref)				
Sexohd	-0.032	0.056	-0.571	0.2840
Female	0.052	0.053	0.981	0.1633
Male(ref)				
water	0.063	0.028	2.25	0.0122*
Surface water	-0.087	0.035	-2.486	0.0065*
Well water	0.064	0.072	0.889	0.1870
Piped water(ref.)				
Toilot	0.022	0.066	0.333	0.3696
Have Facilities	-0.063	0.063	-1.000	0.1587
No facilities(ref.)				
Diarrhea	-0.356	0.051	-6.980	0.0000*
Yes	-0.259	0.049	-5.286	0.0000*
No(ref.)				
Fever	-0.017	0.051	-0.333	0.3696
Yes	-0.007	0.049	-0.143	0.4432
No(ref.)				
Random part				
$\sigma^2_{0u} = \text{var}(U_{0j})$	0.023	0.012	1.917	0.0138*
$\sigma^2_{e} = \text{var}(\varepsilon_{0j})$	0.924	0.023	40.174	0.0000*

* Significant ($p<0.05$) ref. = reference category

4.3.3 Determinants of health and nutrition status of Children in terms H/A z-scores (stunting) at National level

Table 4.3.2 Univariate Multilevel Linear Regression model for stunting in children and their Deviance based chi-square test

	Empty model	Random intercept model	Random coefficient model
-2loglikelihood	11357.180	10979.66	10936.29
Deviance-based chi-square value	69.87	528.490	43.37
P-value	0.0000*	0.0000*	0.0240*

* Significant (p<0.05)

The significant deviance-based chi-square value indicated in the above table for the empty model implies that an empty model for stunting with random effect is better than an empty model for stunting without random effect (see Appendix B). Similarly, the significant deviance-based chi-square value for random intercept model indicates that the random intercept and fixed slope model is a better fit as compared to the empty model to describe stunting

Also the deviance-based chi-square test for significance of random effects for random slope model is statistically significant. This implies that in comparison to the model with random intercept and fixed slope model, the model with random intercept and random coefficients provides a better fit in explaining regional differences in the nutritional/health status of children in terms of stunting. Thus, among the univariate multilevel linear regression models for stunting, the random intercept and random slope model fits significantly better than the others.

4.3.4 Determinants of health and nutrition status of children in terms H/A z-scores (stunting) at National level: Random Intercept and Random Slope Model

The random coefficient model is useful because it shows how much variability exists at each level. Results of random coefficient model for stunting (see Appendix B) are obtained by including level-2 random coefficients for socio-economic, demography, and health and environmental characteristics except employment status of partners and birth order of children, because including the covariance of the random slope of these two variables in the model led to failure of convergence of the estimating algorithm. Also the random slope variance of DIAHREA, Memply, Windex, Fever, Plread, Sexoch and Sexohd are estimated by zero since the fixed effect of the model is not affected by adding a random part for those variables. Therefore, those random slopes are excluded from the model. Thus, result of Table 4.3.4 below is obtained by including level-2 random coefficients of Pedu, Medu, Aochild, Water, Toilot, and HHmem and an overall (level-2) or regional variance constant term (σ_0^2) together with variance and covariance terms representing the random effects of the predictors.

Results from the fixed part of the model clearly show the relationship between health/nutritional status of children in terms of stunting and socio-economic, demographic, and health and environmental variables. Thus, educational status of partners, educational status of mothers, age of child, diahrea, sources of drinking water, employment status of mother, household economic status, place of residence and sex of children are found significant determinants of variation in health/nutrition stunting status of children.

Table 4.3.4 Random intercept and random slope (coefficient) model for stunting

Fixed Part	**Estimate**	**S.E.**	**Z-value**	**P-value**
Intercept (X_0)	-1.042	0.14	-7.443	0.0000*
Employment status of partners (X_1)	0.086	0.112	0.7679	0.2213
Education status of partners (X_2)	0.143	0.048	2.979	0.0015*
Education status of mothers (X_3)	0.122	0.056	2.179	0.0147*
Age of child (X_4)	-0.270	0.017	-15.882	0.0000*
Diarrhea (X_5)	-0.401	0.071	-5.648	0.0000*
Source of drinking water (X_6)	0.088	0.038	2.316	0.0103*
Birth order of child (X_7)	-0.044	0.029	-1.517	0.0646
Employment status of mothers (X_8)	-0.104	0.058	-1.793	0.0365*
Household Economic Status (X_9)	0.098	0.053	1.849	0.03221*
Fever (X_{10})	0.052	0.071	0.732	0.2321
Toilet Facilities (X_{11})	0.012	0.089	0.135	0.4463
Please of residence (X_{12})	0.308	0.144	2.139	0.0162*
Sex of child (X_{13})	-0.109	0.050	-2.180	0.0146*
Sex of Household head (X_{14})	-0.104	0.077	-1.351	0.0884

Household members (X_{15})	0.084	0.144	0.583	0.2800
Random Part	**Estimate**	**S.E.**	**Z-value**	**P-value**
Random Coefficient:				
Level-2 variance and covariance				
$\sigma_{0}^{2} = \mathrm{var}(U_{0j})$	0.373	0.288	1.295	0.0489*
$\sigma_{2}^{2} = \mathrm{var}(U_{2j})$	0.059	0.050	1.180	0.0595
$\sigma_{3}^{2} = \mathrm{var}(U_{3j})$	0.023	0.067	0.343	0.1829
$\sigma_{4}^{2} = \mathrm{var}(U_{4j})$	0.006	0.007	0.857	0.09786
$\sigma_{6}^{2} = \mathrm{var}(U_{6j})$	0.022	0.027	0.815	0.1038
$\sigma_{11}^{2} = \mathrm{var}(U_{11j})$	0.092	0.145	0.635	0.1314
$\sigma_{15}^{2} = \mathrm{var}(U_{15j})$	0.223	0.080	2.786	0.0013*
$\sigma_{02} = \mathrm{cov}(U_{0j},U_{2j})$	-0.201	0.092	-2.185	0.01444*
$\sigma_{03} = \mathrm{cov}(U_{0j},U_{3j})$	-0.088	0.110	-0.800	0.2119
$\sigma_{04} = \mathrm{cov}(U_{0j},U_{4j})$	-0.033	0.036	-0.917	0.1796
$\sigma_{06} = \mathrm{cov}(U_{0j},U_{6j})$	0.128	0.074	1.730	0.04182*
$\sigma_{011} = \mathrm{cov}(U_{0j},U_{11j})$	-0.063	0.169	-0.373	0.3546
$\sigma_{015} = \mathrm{cov}(U_{0j},U_{15j})$	-0.193	0.120	-1.608	0.05392
$\sigma_{23} = \mathrm{cov}(U_{2j},U_{3j})$	0.009	0.044	0.205	0.4188
$\sigma_{24} = \mathrm{cov}(U_{2j},U_{4j})$	-0.001	0.014	-0.071	0.4717
$\sigma_{26} = \mathrm{cov}(U_{2j},U_{6j})$	-0.070	0.028	-2.500	0.0062*
$\sigma_{211} = \mathrm{cov}(U_{2j},U_{11j})$	0.160	0.065	2.462	0.0070*
$\sigma_{215} = \mathrm{cov}(U_{2j},U_{15j})$	0.047	0.046	1.022	0.1534
$\sigma_{34} = \mathrm{cov}(U_{3j},U_{4j})$	-0.019	0.017	-1.118	0.1318
$\sigma_{36} = \mathrm{cov}(U_{3j},U_{6j})$	0.043	0.037	1.162	0.1226
$\sigma_{311} = \mathrm{cov}(U_{3j},U_{11j})$	0.038	0.079	0.481	0.3153
$\sigma_{315} = \mathrm{cov}(U_{3j},U_{15j})$	0.046	0.057	0.807	0.2098
$\sigma_{46} = \mathrm{cov}(U_{4j},U_{6j})$	0.006	0.010	0.600	0.2743
$\sigma_{411} = \mathrm{cov}(U_{4j},U_{11j})$	-0.020	0.020	-1.000	0.1587
$\sigma_{415} = \mathrm{cov}(U_{4j},U_{15j})$	0.006	0.017	-0.353	0.3620
$\sigma_{611} = \mathrm{cov}(U_{6j},U_{11j})$	-0.082	0.061	-1.344	0.0895
$\sigma_{615} = \mathrm{cov}(U_{6j},U_{15j})$	-0.117	0.035	-3.343	0.0004*
$\sigma_{1115} = \mathrm{cov}(U_{11j},U_{15j})$	0.034	0.085	0.400	0.3446
Level-one variance:				
$\sigma_{e}^{2} = \mathrm{var}(\varepsilon_{0j})$	1.812	0.057	31.790	0.0000*

*Significant ($p<0.05$)

In the above table, the value of Var (U_{0j}), Var (U_{2j}), Var (U_{3j}), Var (U_{4j}), Var (U_{6j}), Var (U_{11j}) and Var (U_{15j}) are the estimated variances of intercept, slope of Pedu, slope of Medu, slope of Aochild, slope of Water, slope of Toilet and slop of HHmem, respectively.

Among those estimated variances, only the intercept and HHmem p-values are small, suggesting that intercepts for regions and slope of number of household members vary significantly, that is, there is only a significant variation in the effects of the number of household members across the regions in terms of stunting.

Similarly, the interaction of the random parts of education status of partners and source of drinking water, education status of partners and toilet facility, and sources of drinking water and number of household members are significantly differ across regions.

4.4 Determinants of health and nutrition status of children: A Multivariate Multilevel Linear Regression Analysis

To define a multivariate model, in our case of a 2-variate model, we treat region as level 3, children as a level 2 and within-nutrition/health status measurements (stunting and underweight) as level 1 unit. But there is no level 1 variation specified because level 1 exists solely to define the multivariate structure.

We use multivariate multilevel analysis for comparisons and for joint analysis of the effects of socio-economic, demographic, and health and environmental variables on the measures of health/nutrition status (stunting and underweight) of children across regions and to estimate any residual correlation between stunting and underweight.

Table 4.4 A Multivariate Multilevel Linear Regression model for underweight and stunting in children and their deviance-based chi-square test

	Multivariate Empty model	Multivariate random intercept model	Multivariate random coefficient model
-2loglikelihood	18080.42	17598.20	17554.74
Deviance-based chi-square value	180.47	482.22	43.45
P-value	0.0000*	0.0000*	0.1837

The deviance-based chi-square value for multivariate empty model shown in Table 4.4 is the difference in log likelihoods between a multivariate empty model for stunting and underweight without random effect and a multivariate empty model for stunting and underweight with random effect (see Appendix B), which is to be compared with the critical value from the chi-squared distribution with 1 degree of freedom. This implies that a multivariate empty model with random effect is better than a multivariate empty model without random effect.

Likewise, the significant deviance-based chi-square value for multivariate random intercept model indicates that the multivariate random intercept and fixed slope model is a better fit as compared to the multivariate empty model.

Also the deviance-based chi-square value for significance of random effects for multivariate random slope model is statistically insignificant. This implies that in comparison to the model with multivariate random intercept and fixed slope model the multivariate random intercept and random coefficients model has poor fit.

Thus, the deviance-based chi-square test shown in Table 4.4 implies that among the multivariate multilevel linear regression models, the multivariate random intercept and fixed slope model fits significantly better than the others.

4.5 Determinants of nutrition and health status of children using Multivariate Multilevel Random Intercept Linear Regression Model

Table 4.5 shows the joint analysis of the effects of socio-economic, demographic, and health and environmental characteristics on the measures of health/nutrition status of children (stunting and underweight) and the estimates of residual covariance between stunting and underweight. There is a significant difference between the sum of the two -2loglikelihhod's of the separate analysis for random intercept model of underweight and stunting (see Appendix B) and the -2loglikelihood of the multivariate random intercept model in which stunting and underweight are analysed together $(X^2 = 2092.744;\ p < 001)$. This significant test indicates that estimation as a MVML random intercept model is preferred to separate estimation of multilevel random intercept models, and implies the presence of correlation among stunting and underweight.

The fixed part of Table 4.5 below shows that place of residence, employment status of mother, education status of mother, education status of partners, age of child, birth order of children, sex of child, source of drinking water and diahrea are jointly statistically significant explanatory variables on both stunting and underweight. Household economic status and partner employment status are significant only in terms of underweight and number of household member is significant only in terms of stunting.

As can be seen in Table 4.5, on average, children from unemployed mothers are less vulnerable to malnutrition and health problems than children from employed mothers in terms of both stunting and underweight. Likewise, on average children who live in a poor household are highly vulnerable to health problem and malnutrition than children who reside in a rich household in terms of underweight. However it is statistically insignificant in terms of stunting.

Table 4.5 also portrays children in age group less than 6 months have better nutrition and health status, on average, than children in age group 47-59 months in terms of both stunting and underweight. Children in age group 6-11 months have also on average better nutrition and health status than those in age groups 47-59 months in terms of stunting while those are worse than children in age groups 47-59 months in terms of underweight. Similarly, on average children who had diarrhea in the two weeks before the survey date are highly vulnerable to health problem and malnutrition as compared those who have not in terms of both stunting and underweight.

The random part of the model shows that stunting has a larger variance at both the region and child level than underweight. There is also a significant positive correlation between stunting and underweight at child level.

Table 4.5 multivariate random intercept mode at national level

Covariates	Estimate		S.E		Z_{cal}		p-value	
	Stunting	underweight	Stunting	Underweight	Stunting	Under weight	Stunting	under weight
Intercept	-1.352	-0.791	0.266	0.187	-5.083	-2.974	0.0000*	0.0015*
Plread	0.365	-0.046	0.151	0.021	2.417	-2.190	0.0078*	0.0143*
Urban	0.228	-0.035	0.160	0.112	1.425	-0.313	0.0771	0.3771
Rural(ref.)								
Memloy	-0.106	-0.099	0.058	0.041	-1.828	-2.415	0.0338*	0.0079*
Unemployed	0.103	0.071	0.056	0.039	1.839	1.821	0.0330*	0.0343*
Employment (ref)								
Windex	0.080	0.069	0.054	0.038	1.482	1.816	0.0692	0.0347*
Poor	-0.193	-0.195	0.149	0.101	-1.295	-1.931	0.0977	0.0267*
Medium	-0.116	-0.125	0.145	0.101	-1.145	-1.238	0.1261	0.1077
Rich(ref.)								
Pemploy	0.100	0.178	0.114	0.080	0.877	2.225	0.1902	0.0130*
Agricultural	-0.067	-0.192	0.109	0.076	-0.615	-2.526	0.2693	0.0058*
Non agricultural (ref.)								
Medu	0.102	0.192	0.061	0.043	-1.672	4.465	0.0473*	0.0000*
No education	-0.153	-0.452	0.158	0.110	-0.968	-4.109	0.1665	0.0000*
Primary	-0.024	-0.298	0.156	0.108	-0.154	-2.759	0.4388	0.0029*
Secondary & above(ref.)								
Pedu	0.159	0.138	0.047	0.033	3.383	4.182	0.0004*	0.0000*
No education	-0.392	-0.241	0.106	0.074	-3.698	-3.257	0.0001*	0.0006*
Primary	-0.257	-0.130	0.103	0.072	-2.495	-1.806	0.0063*	0.0355*
Secondary & above(ref.)								
HHmem	0.118	0.069	0.060	0.043	1.967	1.605	0.0246*	0.0543
1-4	-0.076	-0.076	0.112	0.078	-0.679	-0.974	0.2486	0.1650
5-9	-0.122	-0.079	0.104	0.072	-1.173	-1.097	0.1204	0.1363
10+(ref.)								
Aochild	-0.278	-0.153	0.017	0.012	16.353	-12.75	0.0000*	0.0000*
<6	1.834	1.283	0.104	0.073	17.635	17.575	0.0000*	0.0000*
6-11	1.064	-0.341	0.103	0.072	10.330	-4.734	0.0000*	0.0000*
12-23	0.163	-0.021	0.079	0.055	2.063	-0.382	0.0196*	0.3512
24-35	0.151	0.000	0.078	0.055	1.936	0.0000	0.0264*	0.5000
36-47	0.125	0.053	0.074	0.052	1.689	1.019	0.0456*	0.1541
48-59(ref.)								
Bord	-0.050	-0.046	0.029	0.021	-1.724	-2.191	0.0424*	0.0142*
1	0.100	0.114	0.080	0.056	1.250	2.036	0.1057	0.0209*
2-3	-0.028	0.007	0.066	0.046	-0.424	0.152	0.3358	0.4396
4-5	-0.071	-0.061	0.069	0.048	-1.029	-1.271	0.1517	0.1017
6+(ref.)								
Sexoch	-0.120	0.040	0.051	0.021	-2.353	1.905	0.0093*	0.0284*
Female	0.109	0.033	0.050	0.035	2.180	0.943	0.0146*	0.1728
Male(ref)								
Sexohd	-0.106	-0.035	0.079	0.056	-1.342	-0.625	0.0901	0.2660
Female	0.119	0.047	0.076	0.053	1.566	0.887	0.0587	0.1875
Male(ref)								
Water	0.100	0.065	0.039	0.027	2.564	2.407	0.0052*	0.0080*
Surface water	-0.119	-0.092	0.080	0.055	-1.293	-1.673	0.0980	0.0472*
Well water	0.048	0.062	0.103	0.072	0.466	0.861	0.3206	0.1946
Piped water(ref.)								
Toilot	-0.043	0.024	0.093	0.066	-0.462	0.364	0.3220	0.3579
Have Facilities	-0.038	-0.010	0.090	0.065	-0.422	-0.154	0.3365	0.4388
No facilities(ref.)								
Diahrea	-0.398	-0.358	0.072	0.051	-5.528	-7.020	0.0000*	0.0000*
Yes	-0.288	-0.261	0.071	0.049	-4.056	-5.327	0.0000*	0.0000*
No(ref.)								
Fever	0.059	-0.016	0.072	0.057	0.819	0.281	0.2064	0.3894
Yes	0.081	-0.008	0.071	0.049	1.141	-0.163	0.1269	0.4353
No(ref.)								

Random Part	**Variance Component**	**S.E**	**Z-value**	**p-value**
Level-three variance:				
$\sigma^2_{0V} = \text{var}(V_{0k})$	0.036	0.019	1.895	0.0145*
$\sigma^2_{1V} = \text{var}(V_{1k})$	0.023	0.012	1.917	0.0139*
$\sigma_{01V} = \text{cov}(V_{0k}, V_{1k})$	0.016	0.012	1.333	0.0913
Level-two variance:				
$\sigma^2_{0u} = \text{var}(U_{0k})$	1.901	0.048	39.604	0.0000*
$\sigma^2_{1u} = \text{var}(U_{1k})$	0.924	0.023	40.174	0.0000*
$\sigma_{01u} = \text{cov}(U_{0k}, U_{1k})$	0.93	0.029	32.035	0.0000*

* Significant ($p<0.05$)
ref. = reference category
0= stunting
1= underweight

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 DISCUSSION

This study was intended to identify the determinants of the health/nutritional status of children based on EDHS 2005 data. Accordingly, separate multiple linear regression and multilevel linear regression techniques on stunting and underweight were employed. In addition to this multivariate multilevel linear regression techniques jointly on stunting and underweight were employed. The results obtained are discussed as follows.

Concerning the regional disparity in children's health/nutritional status, the results from both underweight and stunting models confirmed that children who live in Amhara, Somali, Tigray, SNNP, Oromia, Ben-Gumz and Afar are, on average, at a higher risk of malnutrition/health problem than children who live in Addis Ababa. Moreover, children in Harari are at a higher risk of health problem/malnutrition in terms of stunting than children who live in Addis Ababa. The observed higher risk of malnutrition in Tigray, Amhara and SNNP regions may be attributed to differences in cultural and dietary practices (Woldemariam and Timotiwos, 2002).

The findings of the study show that the risk of malnutrition/health problem is significantly less, on average, for children whose mothers are unemployed than children from employed mothers in Ethiopia in terms of both underweight and stunting. This may be because of the fact that time allocated to earning income may be at the expense of time spent in feeding and caring for children (Alemu et al., 2005a). Moreover, since the majority of mothers in developing countries like Ethiopia work in the informal sector and in lower status jobs, the amount of income for these mothers is low and would have a negligible impact on the nutritional status of children.

The findings of this study also show that there is a significant difference in the risk of nutrition and health status in children by mothers' educational level in terms of underweight. The risk of malnutrition/health problem is, on average, significantly higher for children whose mothers have no education and primary education level than children whose mothers have secondary and higher level of education in terms of long and short-run measures(i.e. underweight). This finding seemed to be consistent with other studies (Oyekale and Oyekale, 2000; Smith and Haddad, 2000). They indicated that education improves the ability of mothers to implement simple health knowledge and facilitates their capacity to manipulate their environment including health care facilities, interact more effectively with health professionals, comply with treatment recommendations, and keep their environment clean. Furthermore, educated women have greater control over health choices for their children.

Household economic status is also an important socio-economic variable that affects health/nutritional status of children in Ethiopia in terms of stunting. Children in poor households are found to be, on average, at a higher risk of malnutrition/health problem than children from rich households. This finding is consistent with other studies (Smith et al., 2005; SCUK, 2002; Woldemariam & Timotewos, 2002). They indicated that better off households have better access to food and higher cash incomes than poor households, allowing them a quality diet, better access to medical care and more money to spend on essential non-food items such as schooling, clothing and hygiene products.

Age of child is also one of the most important determinant factors which affects health/nutritional status of children in Ethiopia in terms of both underweight and stunting. Children up to 6 months have better nutrition/health status than other age groups. This could be because of breastfeeding in the early stages of child growth, mother’s ability to care for the child and also due to the care that parents give to older children that may decline especially if there are younger children in the family (UN, 1985).

Another important demographic factor which affects health/nutritional status of children in Ethiopia in terms of stunting is sex of child. Male children are significantly vulnerable to nutrition/health problems on average. Similar results are also reported from other studies (Christiaensen and Alderman, 2001; Alemu et al., 2005(a, b)). They argued that this could be due to genetic differences between male and female children and, due to girls’ greater access to food through their gender-ascribed role in contributing to food preparation.

The findings of this study also show that children who have diarrhea two weeks before date of survey are significantly vulnerable to malnutrition and health problem than those who have not in terms of both underweight and stunting. This finding is consistent with other studies (Sommerfelt et. al., 1994; WHO, 1986). This is due to the fact that diarrhea accelerates the onset of malnutrition by reducing food intake and increasing catabolic reactions in the organism. Diarrhea also affects both dietary intake and utilization, which may have a negative effect on improved child nutritional status.

Source of drinking water is also an important environmental factor that affects the nutrition/health status of children in Ethiopia in terms of long and short run measure (i.e. underweight). The findings of this study show that children who use water from unprotected as sources of drinking are, on average, highly vulnerable to malnutrition/health problem than those who use pipe water. This is because of access to unsafe water is regarded as the main cause of infectious diseases such as diahrea and intestinal parasites (Smith et al, 2005). Moreover, improving access and quality to safe water not only reduces transmission of waterborne diseases but also saves women the extra time they spend on carrying water which can be allotted to child care and feeding or income generating activities.

Multilevel linear regression analysis is also employed in this study. In this analysis children are considered as nested within the various regions in Ethiopia. In order to explain regional differences in health/nutrition status of children, we employed three multilevel linear regression models for each response variable (underweight and stunting): an empty model, a random intercept and a random intercept and coefficient model. The results obtained are discussed briefly in subsequent sections.

Before the analysis of data using the multilevel approach, first the heterogeneity of the nutritional status of children with regard to regions was checked. The F-test and the empty model suggest that health/nutritional status of children differs among regions both in terms of underweight and stunting. Such heterogeneity is a prerequisite in multilevel analysis.

In general, the fixed parts of the effects of explanatory variables included in the multilevel models have somewhat similar interpretation as that of the multiple linear regression as discussed above. Whereas the random parts of the intercept and the coefficients provide additional information. In both models, the overall variance constant term found to be statistically significant, which implies existence of differences in the health/nutritional status of children in terms of stunting and underweight.

Among the variables included level-2 random coefficients for random coefficient model of stunting, the random part of number of household members on health/nutrition status significantly differ across the regions. Likewise, the interaction of the random parts of education status of partners and sources of drinking water, education status of partners and toilet facilities, and sources of drinking water and number household members have significant effect on health/nutritional status across regions.

Another important statistical analysis used in this study is multivariate multilevel linear regression. In the multivariate multilevel analysis within-nutrition/health status measurements are nested within children and children are considered as nested within the various regions in Ethiopia. Three multivariate multilevel models: an empty model, a random intercept and a random intercept and a random coefficient model were applied in order to explain residual correlation between stunting and underweight and for comparisons and for joint analysis of the effects of explanatory variables on the measures of health/nutrition status of children. From among these multivariate multilevel linear regression models, the multivariate random intercept and fixed slope model fits significantly better than the others.

In multivariate random intercept and fixed slope model the random part of stunting is higher than the random part of underweight at both child and region level. This implies that there is a higher variability of nutrition and health status of stunting than in underweight at both child and region levels.

The fixed part of multivariate random intercept model shows that place of residence, employment status of mother, education status of mother, education status of partners, age of child, birth order of children, sex of child, source of drinking water and diarrhea are jointly statistically significant explanatory variables on measures of nutrition/health status of children in Ethiopia. Household economic status and partner employment status are only significant in terms of underweight and family size is significant only in terms of stunting. The relationships of each explanatory variable to the health/nutrition status of children have almost similar interpretation as that of the multiple linear regressions discussed above.

5.2 CONCLUSIONS AND RECOMMENDATION

The study revealed that socio-economic, demographic and health and environmental variables have significant effect on the nutritional and health status of children in Ethiopia. Place of residence, employment status of mother, educational status of mother, educational status of partners, age of child, birth order of children, sex of child, source of drinking water and diarrhea are the most important determinants of child health/ nutrition status in Ethiopia.

Although there is regionwise disparity in children's health/nutritional status, it is observed that children living in rural parts of the country are at higher risk of health problem and malnutrition. Therefore, it is useful to strengthen health care and food security programs in rural areas to directly address food insecurity and malnutrition problems of the poor and vulnerable communities in rural parts of the country.

The study revealed that children from employed mothers are at a higher risk of health problem and malnutrition. This may be because of the fact that time allotted to earn income might be at the expense of time spent in feeding and caring for children and the majority of mothers work in the informal sectors and in lower status jobs. Therefore, it is useful to develop a policy for mothers to have sufficient time after giving birth and provide formal and qualified job.

The result also suggested that children from uneducated mothers are more vulnerable to health problem/malnutrition in Ethiopia. Therefore, it is useful to improve mothers' access to education in all areas in order to address the problem through improving their income earning capacity and also enhancing the quality of care and attention they can provide to their children.

Children younger than 6 months have better nutrition/health status than other age groups in terms of both underweight and stunting. This could be because of breastfeeding in the early stages of child growth. Thus, efforts should be made to communicate through different programs, such as health and nutritional education, the importance of feeding breast milk exclusively up to 6 months and thereafter introducing other supplementary nutrient rich foods.

The study also revealed that children who use unprotected water as a source of drinking are in high risk to malnutrition/health problem. Thus, efforts should be made to improve access of safe drinking water.

The findings of this study also show that children who have diarrhea two weeks before the date of survey are significantly vulnerable to malnutrition and health problem than those who have not. Therefore, efforts should be made in improving environmental sanitation and personal hygiene to prevent exposure to diarrhea.

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Appendixes

Appendix A: Results of diagnostic checking

Residuals Statistics for stunting at child level

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-3.0700	-.1713	-1.8448	.53999	3108
Std. Predicted Value	-2.454	3.099	.000	1.000	3108
Standard Error of Predicted Value	.052	.180	.103	.024	3108
Adjusted Predicted Value	-3.0074	-.1722	-1.8449	.54006	3108
Residual	-3.00804	3.00177	.00000	1.42221	3108
Std. Residual	-2.376	2.547	.000	.997	3108
Stud. Residual	-2.385	2.560	.000	1.000	3108
Deleted Residual	-3.00372	3.00991	.00015	1.42983	3108
Stud. Deleted Residual	-2.387	2.563	.000	1.000	3108
Cook's Distance	.000	.004	.000	.000	3108
Centered Leverage Value	.001	.016	.005	.003	3108

a Dependent Variable: H/A z-scores

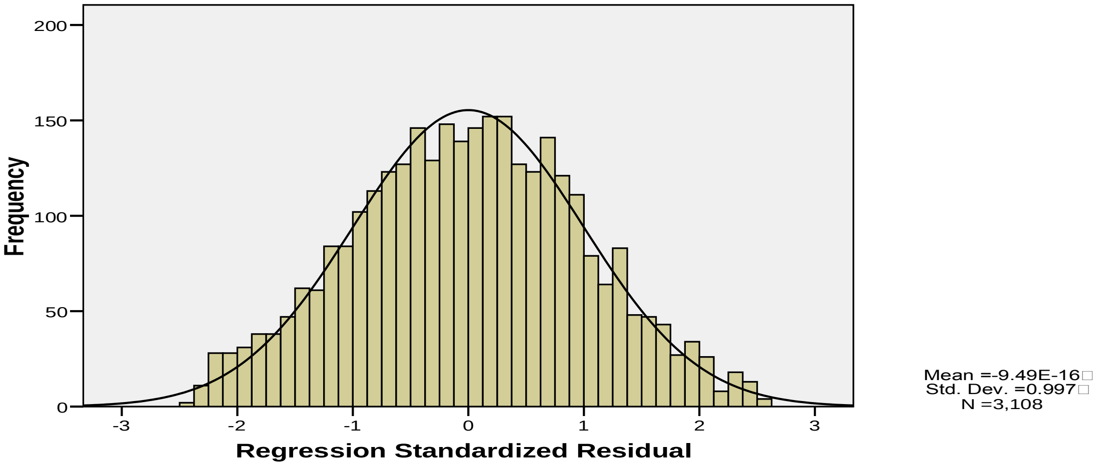
Residuals Statistics for Underweight at child level

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-2.7556	-.4707	-1.6826	.40189	3108
Std. Predicted Value	-2.670	3.016	.000	1.000	3108
Standard Error of Predicted Value	.037	.127	.072	.017	3108
Adjusted Predicted Value	-2.7585	-.4615	-1.6827	.40192	3108
Residual	-2.92874	2.43833	.00000	1.00282	3108
Std. Residual	-2.913	2.425	.000	.997	3108
Stud. Residual	-2.921	2.431	.000	1.000	3108
Deleted Residual	-2.94569	2.44920	.00007	1.00831	3108
Stud. Deleted Residual	-2.925	2.433	.000	1.000	3108
Cook's Distance	.000	.006	.000	.000	3108
Centered Leverage Value	.001	.016	.005	.003	3108

a Dependent Variable: W/A z-scores

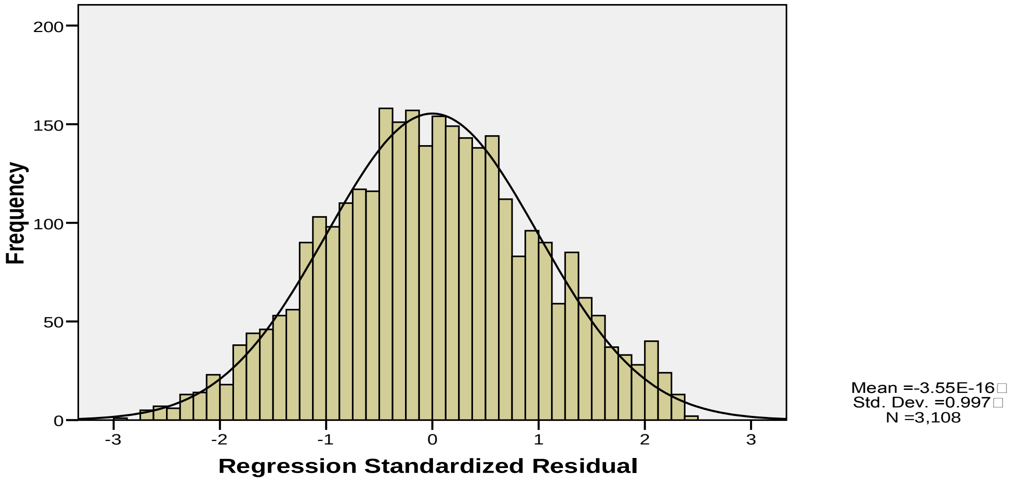
Histogram

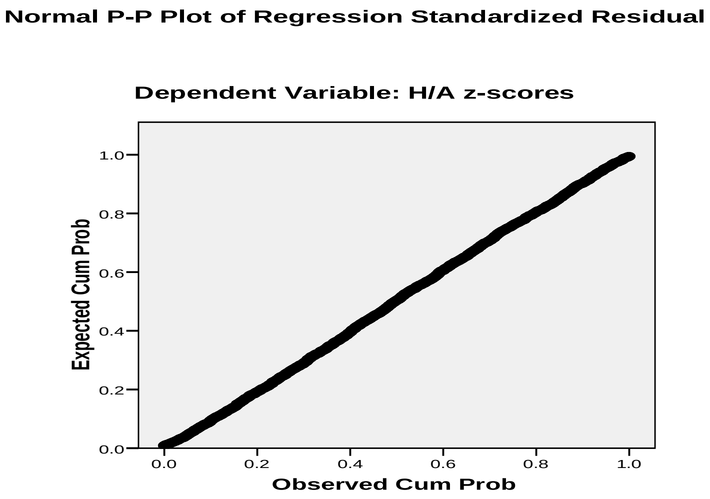
Dependent Variable: H/A z-scores

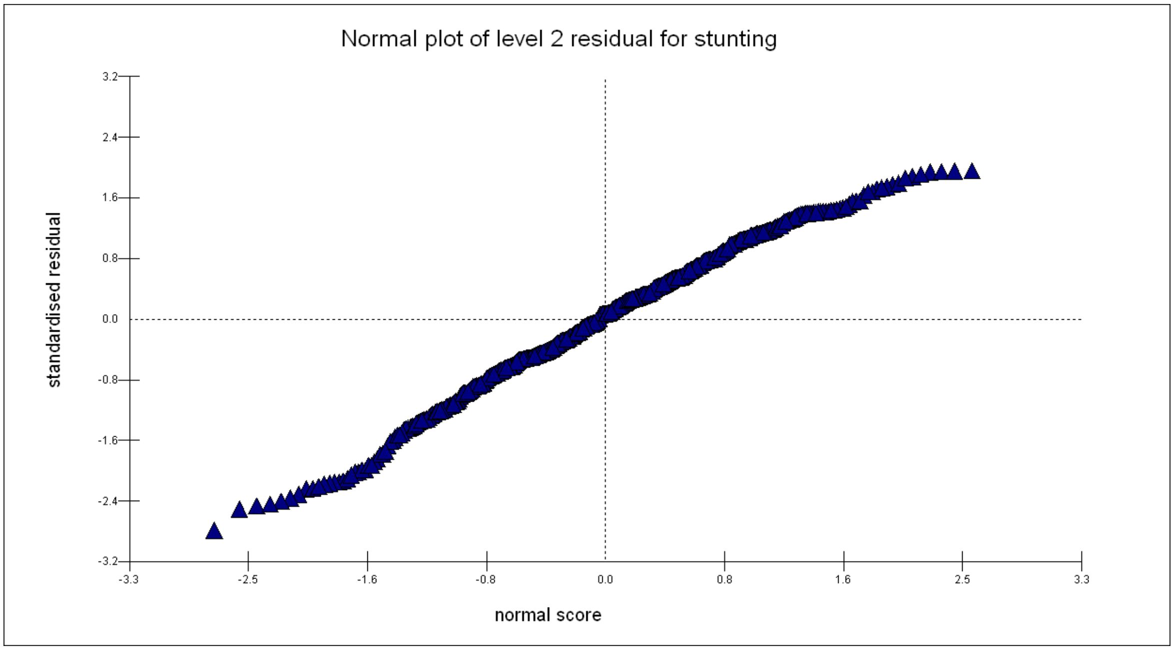


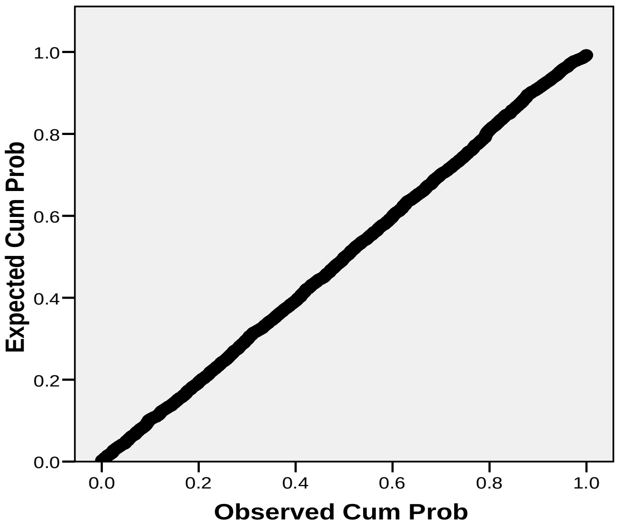
Histogram

Dependent Variable: W/A z-scores



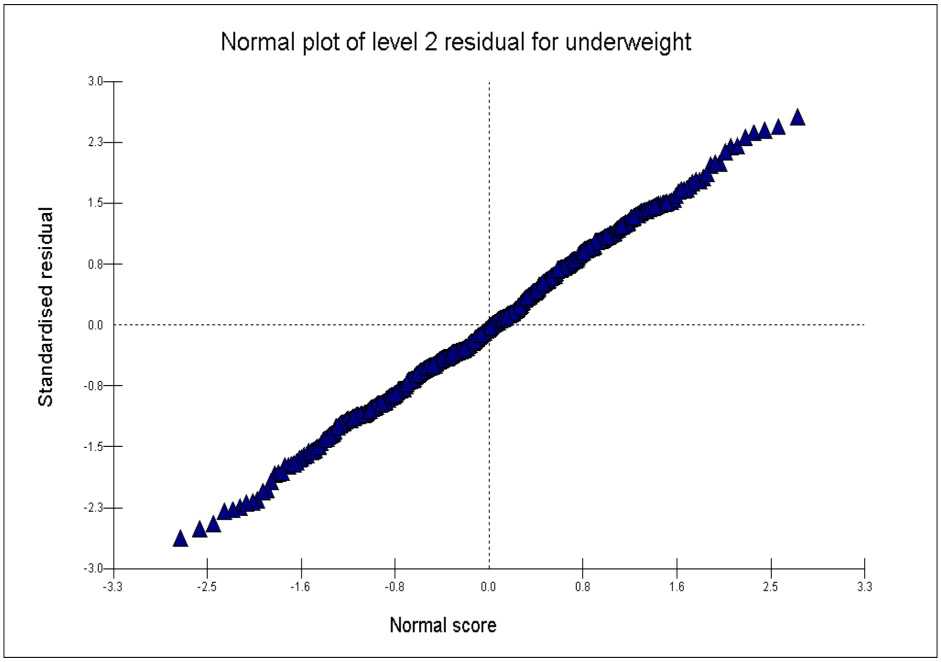

Normal P-P Plot of Regression Standardized Residual
Dependent Variable: H/A z-scores
Expected Cum Prob
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Observed Cum Prob


Normal plot of level 2 residual for stunting
standardised residual
3.2
2.4
1.6
0.8
0.0
-0.8
-1.6
-2.4
-3.2
-3.3
-2.5
-1.6
-0.8
0.0
0.8
1.6
2.5
3.3
normal score



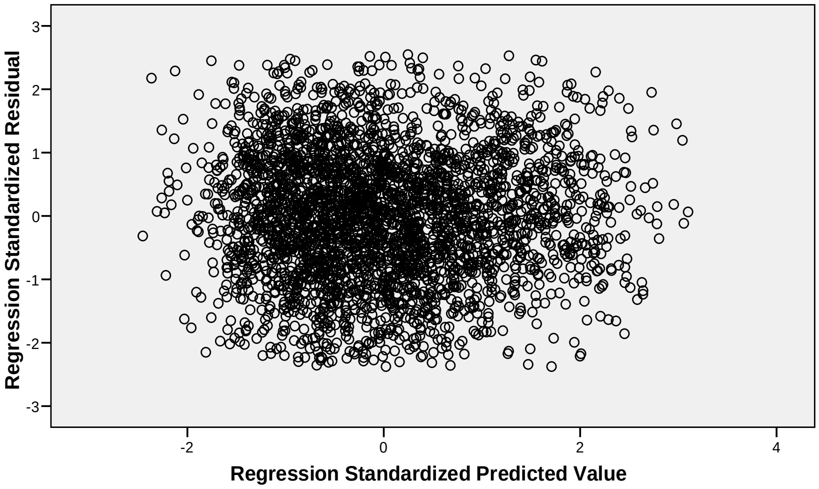
Normal P-P Plot of Regression Standardized Residual

Dependent Variable: W/A z-scores



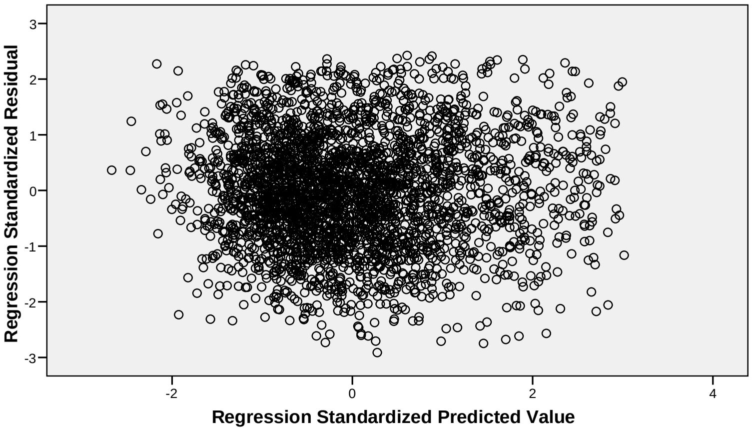
Scatterplot

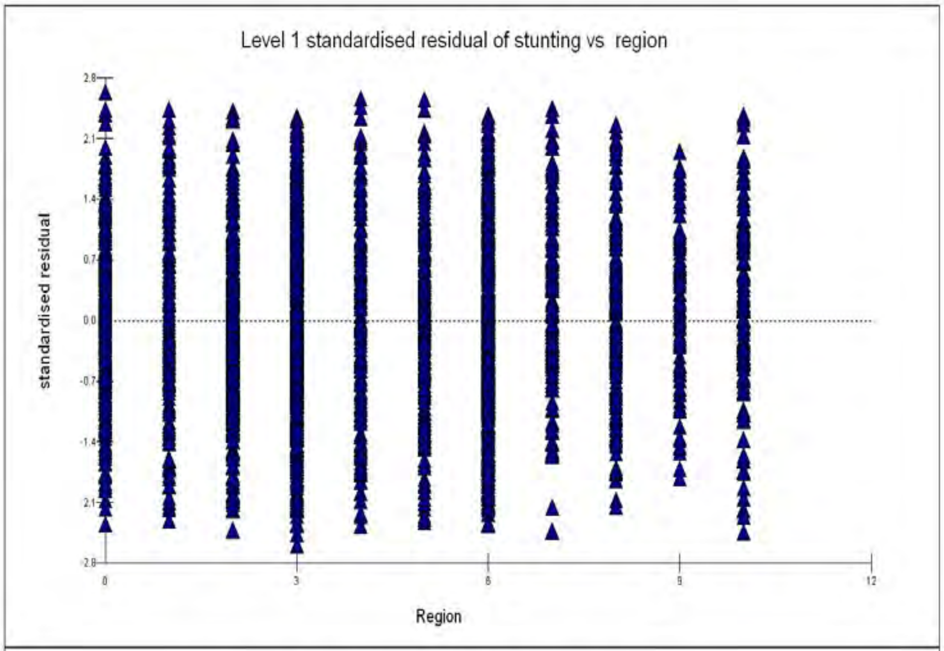
Dependent Variable: H/A z-scores



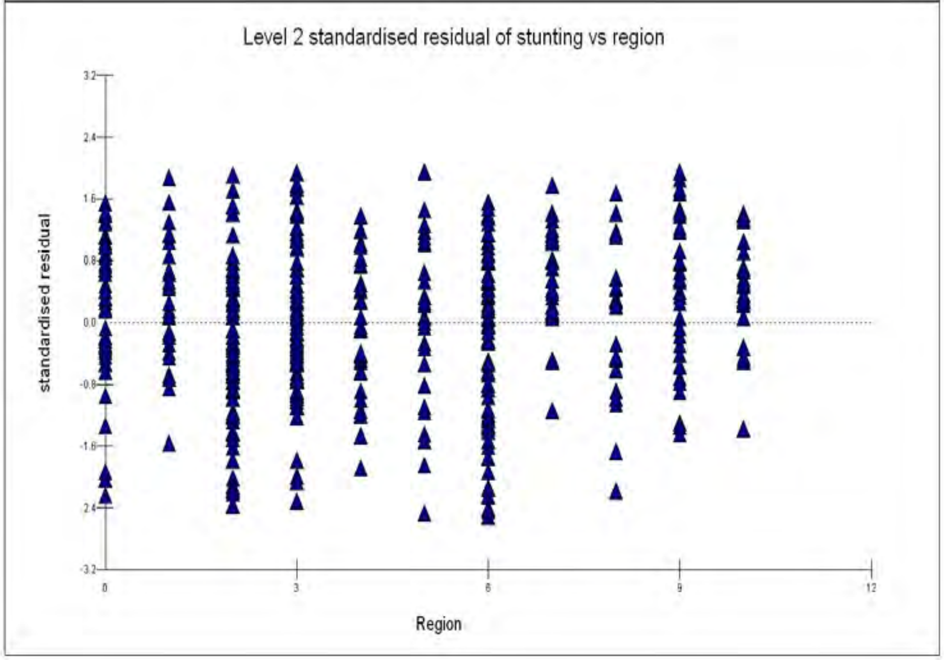
Scatterplot

Dependent Variable: W/A z-scores

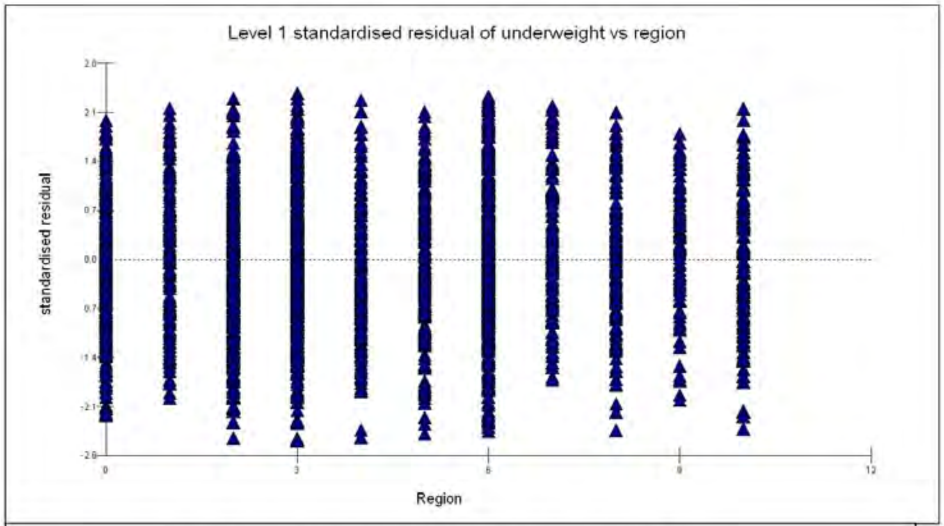


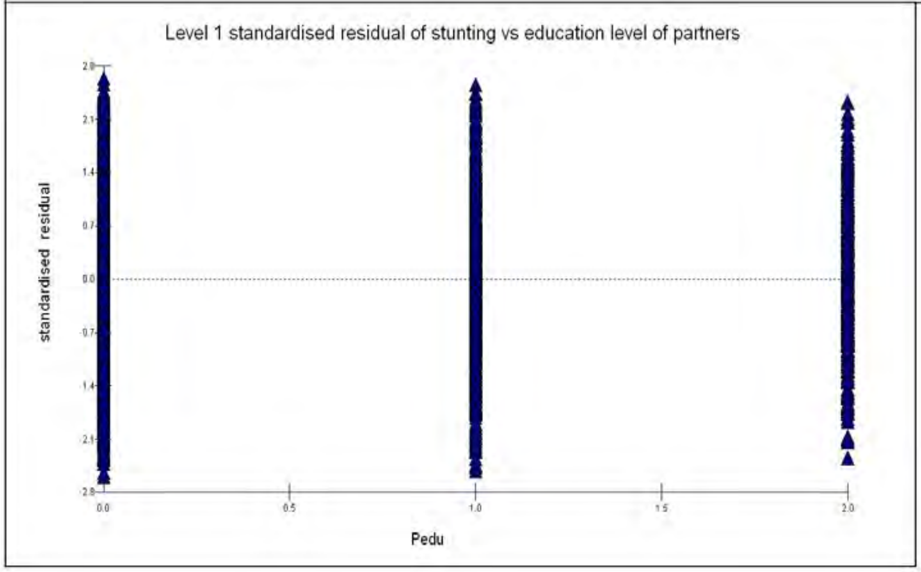


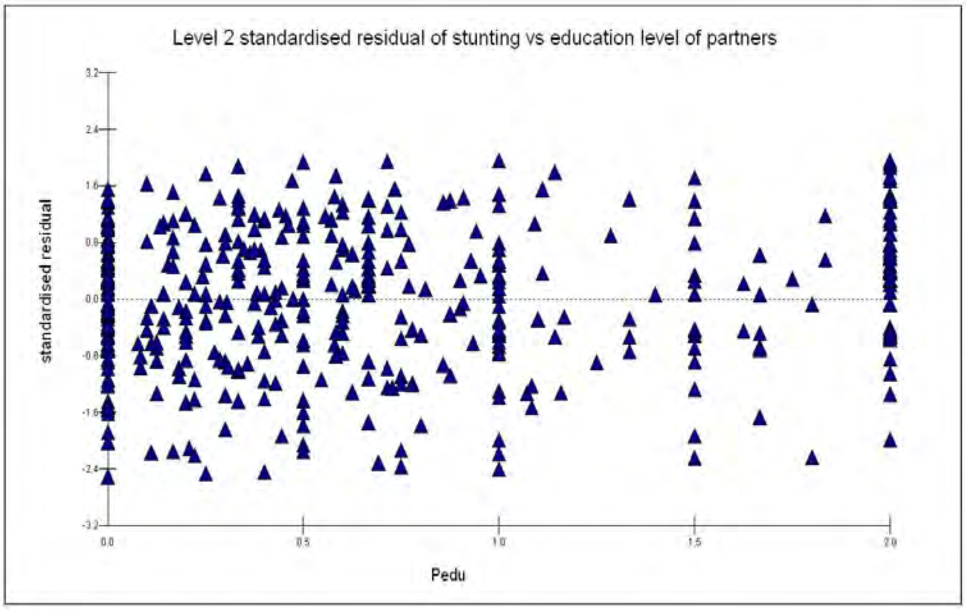
Level 1 standardised residual of stunting vs region

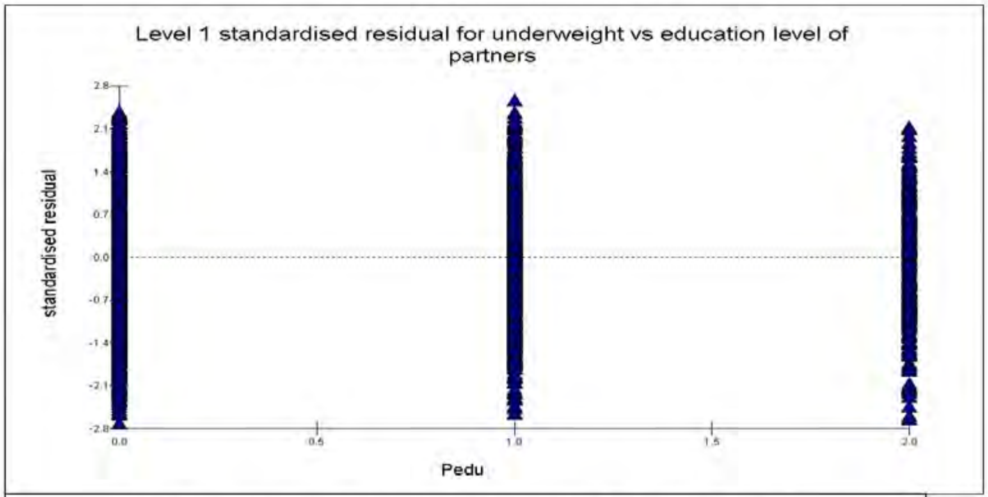


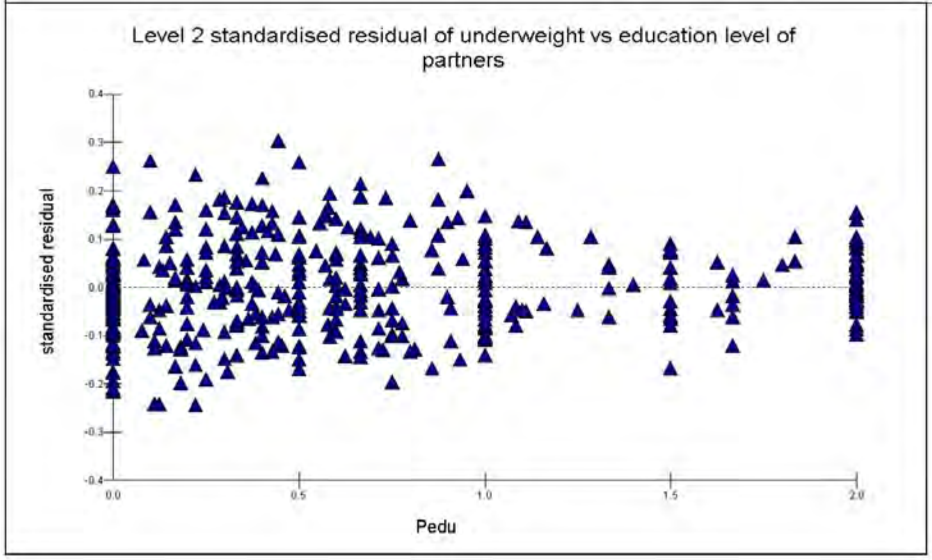
Level 2 standardised residual of stunting vs region

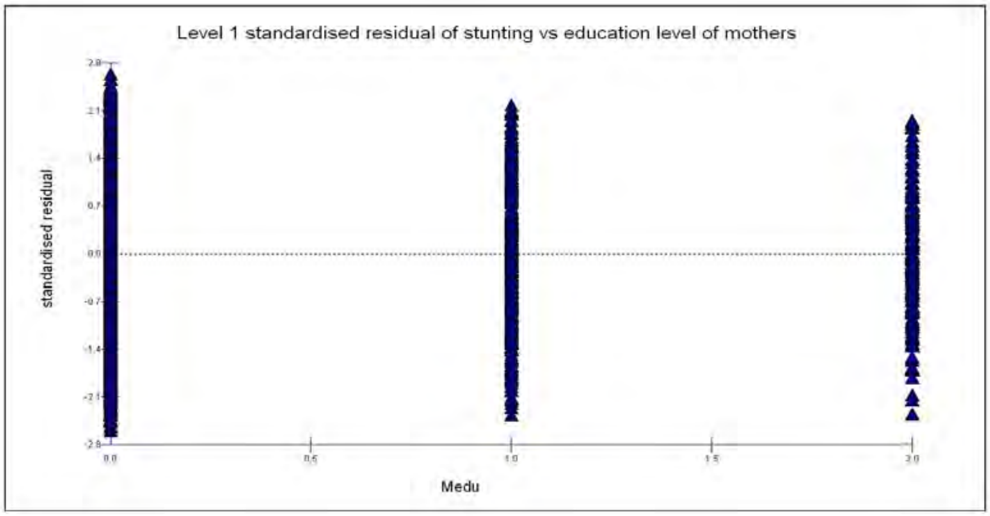

Level 1 standardised residual of underweight vs region

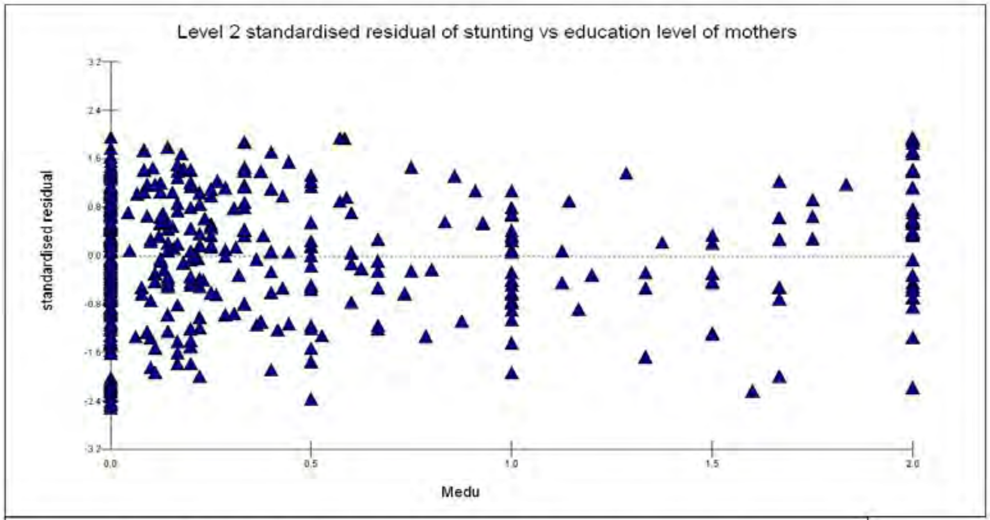

Level 1 standardised residual of stunting vs education level of partners

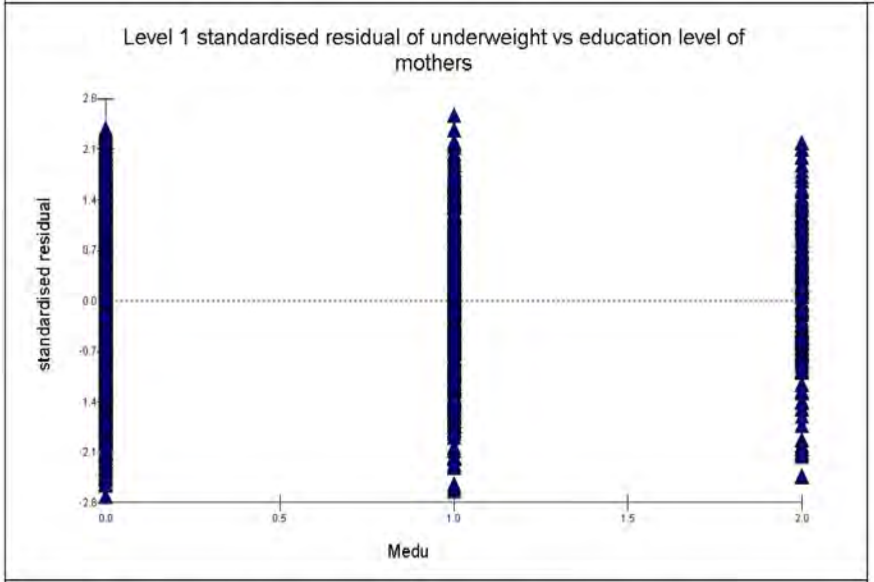

Level 2 standardised residual of stunting vs education level of partners

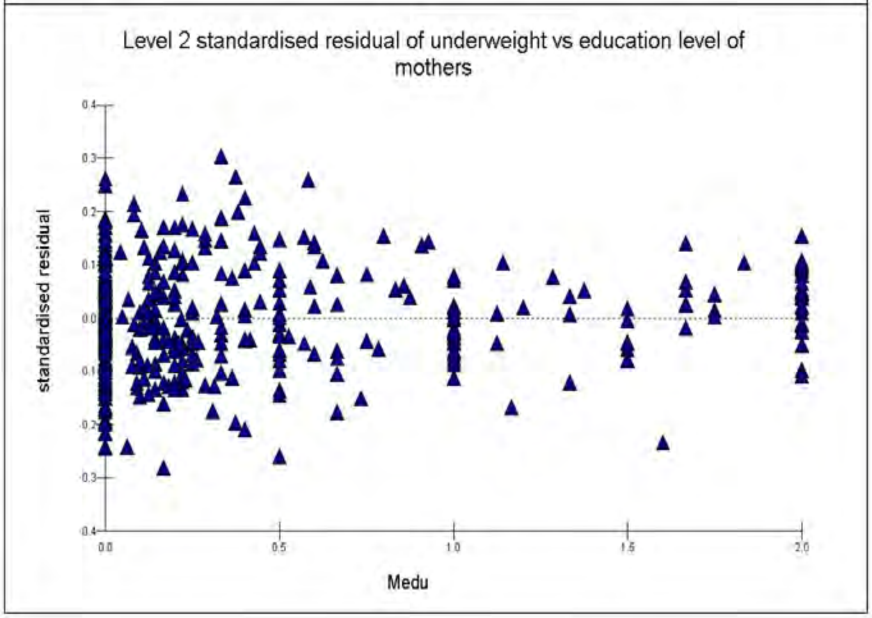

Level 1 standardised residual for underweight vs education level of partners
standardised residual
2.8
2.1
1.4
0.7
0.0
-0.7
-1.4
-2.1
-2.8
0.0
0.5
1.0
1.5
2.0
Pedu


Level 2 standardised residual of underweight vs education level of partners
standardised residual
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0.0
0.5
1.0
1.5
2.0
Pedu

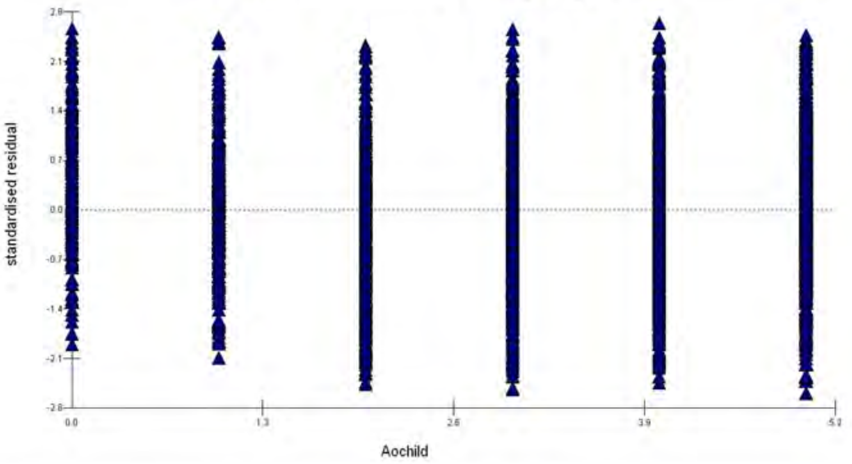

Level 1 standardised residual of stunting vs education level of mothers
standardised residual
2.8
2.1
1.4
0.7
0.0
-0.7
-1.4
-2.1
-2.8
0.0
0.5
1.0
1.5
2.0
Medu


Level 2 standardised residual of stunting vs education level of mothers

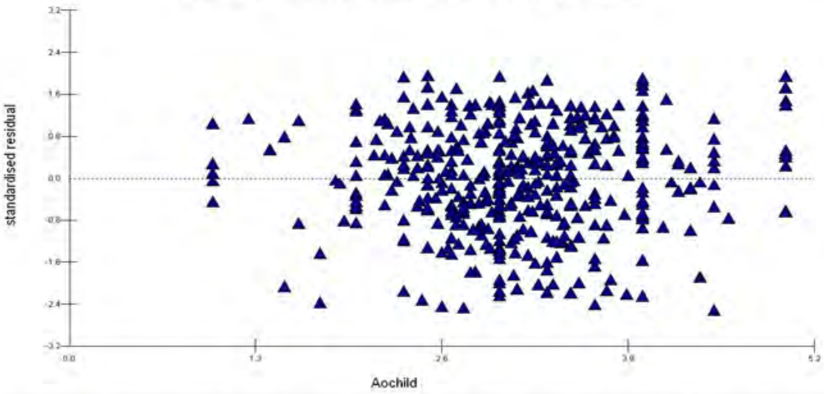

Level 1 standardised residual of underweight vs education level of mothers


Level 2 standardised residual of underweight vs education level of mothers

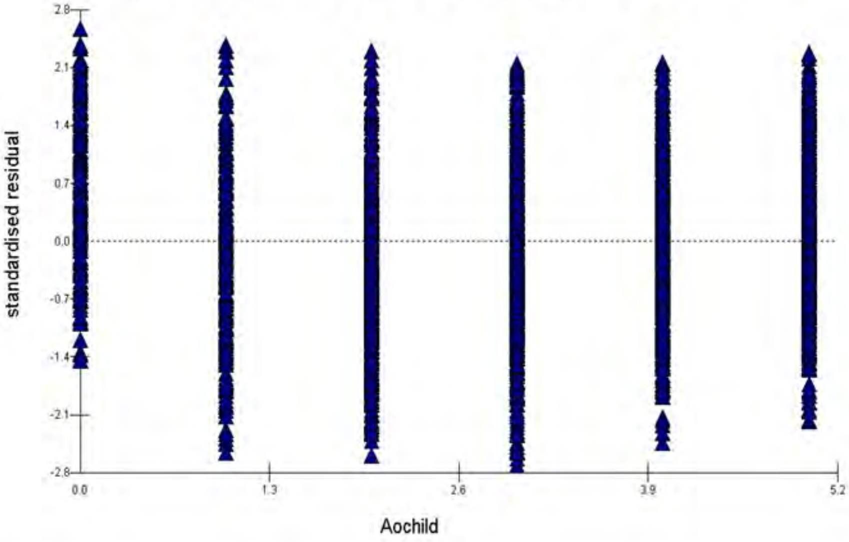
Level 1 standardised residual of stunting vs age of child

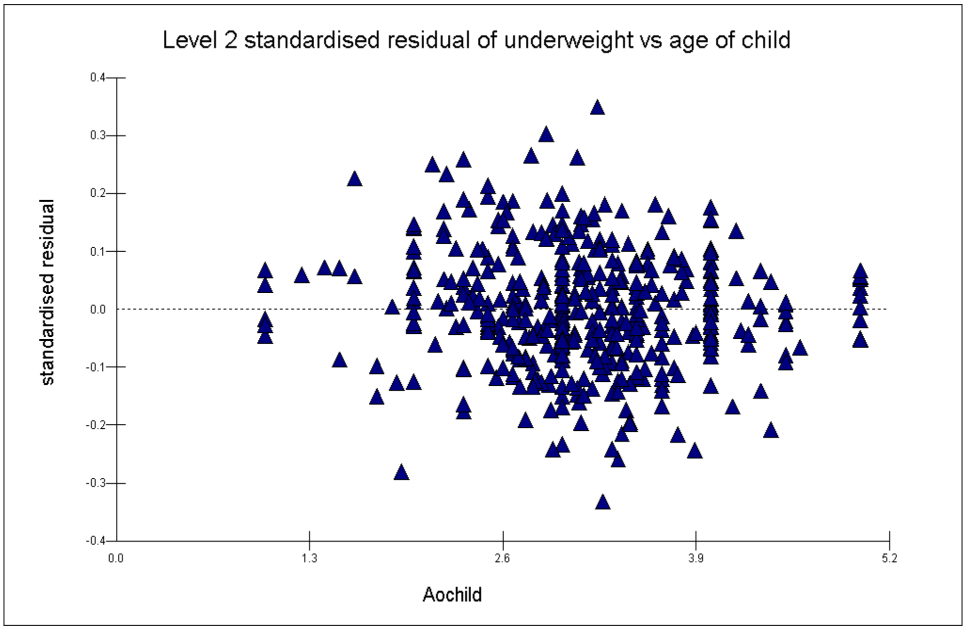


Level 2 standardised residual of stunting vs age of child



Level 1 standardised residual of underweight and age of child





Appendix B: A Univariate and Multivariate Single level and Multilevel Linear Regression Outputs of MLwiN

Empty model for stunting without random effect

$$\text{Stunting}_i \sim \mathrm{N}(XB,\ \Omega)$$

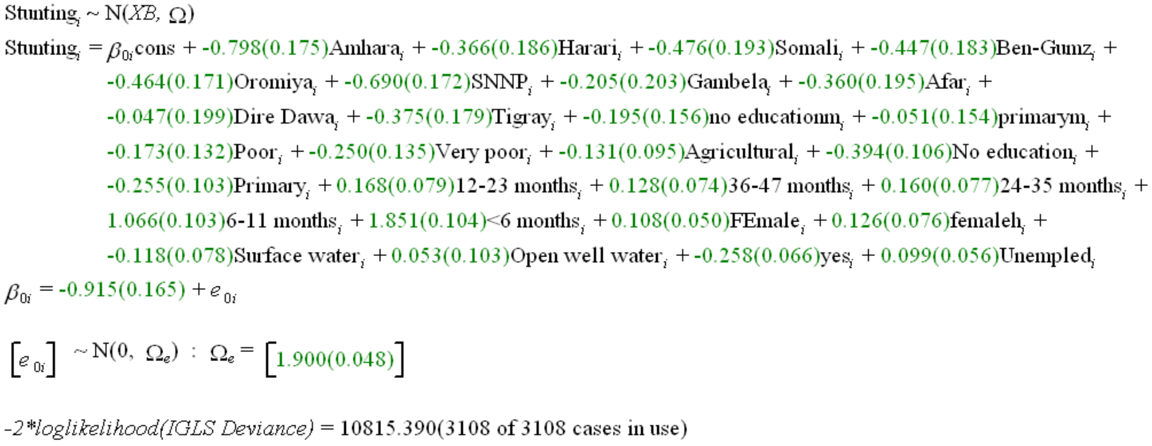
$$\text{Stunting}_i = \beta_{0i}\text{cons}$$

$$\beta_{0i} = -1.845(0.027) + e_{0i}$$

$$\left[e_{0i}\right] \sim \mathrm{N}(0,\ \Omega_e)\ :\ \Omega_e = \left[2.314(0.059)\right]$$

*-2*loglikelihood(IGLS Deviance)* = 11427.050(3108 of 3108 cases in use)

Multiple linear regression models for the selected variables of stunting



$$\text{Stunting}_i \sim \mathrm{N}(XB,\ \Omega)$$

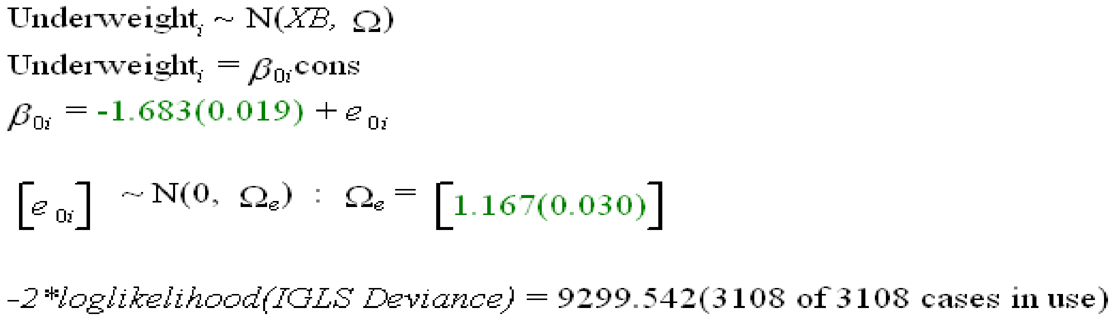
$$\begin{aligned}\text{Stunting}_i = {} & \beta_{0i}\text{cons} + -0.798(0.175)\text{Amhara}_i + -0.366(0.186)\text{Harari}_i + -0.476(0.193)\text{Somali}_i + -0.447(0.183)\text{Ben-Gumz}_i + \\ & -0.464(0.171)\text{Oromiya}_i + -0.690(0.172)\text{SNNP}_i + -0.205(0.203)\text{Gambela}_i + -0.360(0.195)\text{Afar}_i + \\ & -0.047(0.199)\text{Dire Dawa}_i + -0.375(0.179)\text{Tigray}_i + -0.195(0.156)\text{no educationm}_i + -0.051(0.154)\text{primarym}_i + \\ & -0.173(0.132)\text{Poor}_i + -0.250(0.135)\text{Very poor}_i + -0.131(0.095)\text{Agricultural}_i + -0.394(0.106)\text{No education}_i + \\ & -0.255(0.103)\text{Primary}_i + 0.168(0.079)\text{12-23 months}_i + 0.128(0.074)\text{36-47 months}_i + 0.160(0.077)\text{24-35 months}_i + \\ & 1.066(0.103)\text{6-11 months}_i + 1.851(0.104)\text{<6 months}_i + 0.108(0.050)\text{FEmale}_i + 0.126(0.076)\text{femaleh}_i + \\ & -0.118(0.078)\text{Surface water}_i + 0.053(0.103)\text{Open well water}_i + -0.258(0.066)\text{yes}_i + 0.099(0.056)\text{Unempled}_i\end{aligned}$$

$$\beta_{0i} = -0.915(0.165) + e_{0i}$$

$$\left[e_{0i}\right] \sim \mathrm{N}(0,\ \Omega_e)\ :\ \Omega_e = \left[1.900(0.048)\right]$$

*-2*loglikelihood(IGLS Deviance)* = 10815.390(3108 of 3108 cases in use)

Empty model for underweight without random effects



$$\text{Underweight}_i \sim \mathrm{N}(XB,\ \Omega)$$

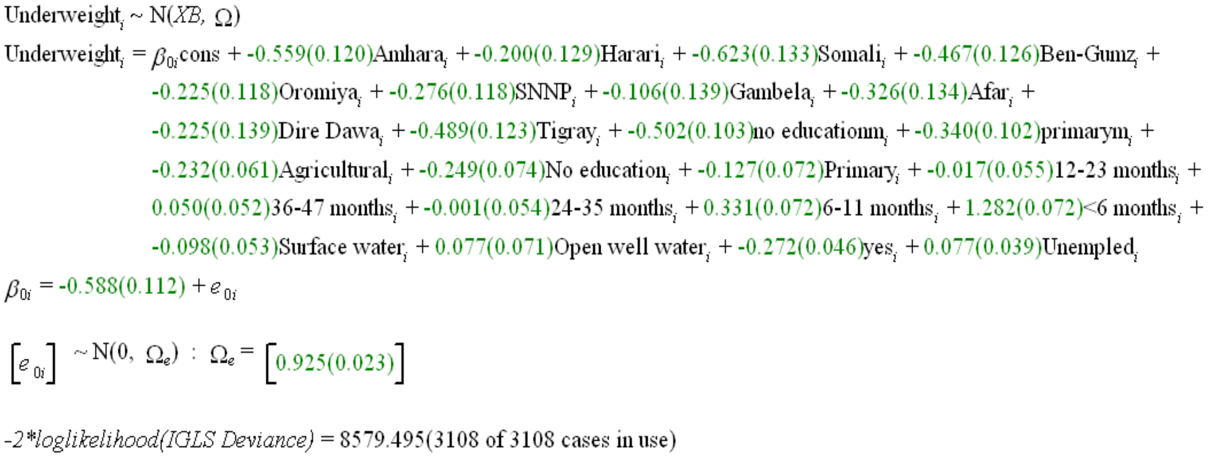
$$\text{Underweight}_i = \beta_{0i}\text{cons}$$

$$\beta_{0i} = -1.683(0.019) + e_{0i}$$

$$\left[e_{0i}\right] \sim \mathrm{N}(0,\ \Omega_e)\ :\ \Omega_e = \left[1.167(0.030)\right]$$

*-2*loglikelihood(IGLS Deviance)* = 9299.542(3108 of 3108 cases in use)

Multiple linear regression model for the selected explanatory variables of underweight



$$\text{Underweight}_i \sim \mathrm{N}(XB,\ \Omega)$$

$$\begin{aligned}\text{Underweight}_i = {} & \beta_{0i}\text{cons} + -0.559(0.120)\text{Amhara}_i + -0.200(0.129)\text{Harari}_i + -0.623(0.133)\text{Somali}_i + -0.467(0.126)\text{Ben-Gumz}_i + \\ & -0.225(0.118)\text{Oromiya}_i + -0.276(0.118)\text{SNNP}_i + -0.106(0.139)\text{Gambela}_i + -0.326(0.134)\text{Afar}_i + \\ & -0.225(0.139)\text{Dire Dawa}_i + -0.489(0.123)\text{Tigray}_i + -0.502(0.103)\text{no educationm}_i + -0.340(0.102)\text{primarym}_i + \\ & -0.232(0.061)\text{Agricultural}_i + -0.249(0.074)\text{No education}_i + -0.127(0.072)\text{Primary}_i + -0.017(0.055)\text{12-23 months}_i + \\ & 0.050(0.052)\text{36-47 months}_i + -0.001(0.054)\text{24-35 months}_i + 0.331(0.072)\text{6-11 months}_i + 1.282(0.072)\text{<6 months}_i + \\ & -0.098(0.053)\text{Surface water}_i + 0.077(0.071)\text{Open well water}_i + -0.272(0.046)\text{yes}_i + 0.077(0.039)\text{Unempled}_i\end{aligned}$$

$$\beta_{0i} = -0.588(0.112) + e_{0i}$$

$$\left[e_{0i}\right] \sim \mathrm{N}(0,\ \Omega_e)\ :\ \Omega_e = \left[0.925(0.023)\right]$$

*-2*loglikelihood(IGLS Deviance)* = 8579.495(3108 of 3108 cases in use)

Empty model for stunting with level-2 random effect

$$\text{Stunting}_{ij} \sim \text{N}(XB, \Omega)$$

$$\text{Stunting}_{ij} = \beta_{0ij}\text{cons}$$

$$\beta_{0ij} = -1.708(0.104) + u_{0j} + e_{0ij}$$

$$\begin{bmatrix} u_{0j} \end{bmatrix} \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \begin{bmatrix} 0.107(0.050) \end{bmatrix}$$

$$\begin{bmatrix} e_{0ij} \end{bmatrix} \sim \text{N}(0,\ \Omega_e)\ :\ \Omega_e = \begin{bmatrix} 2.242(0.057) \end{bmatrix}$$

*-2*loglikelihood(IGLS Deviance)* = 11357.180(3108 of 3108 cases in use)

Random intercept model for stunting

$$\text{Stunting}_{ij} \sim \text{N}(XB, \Omega)$$

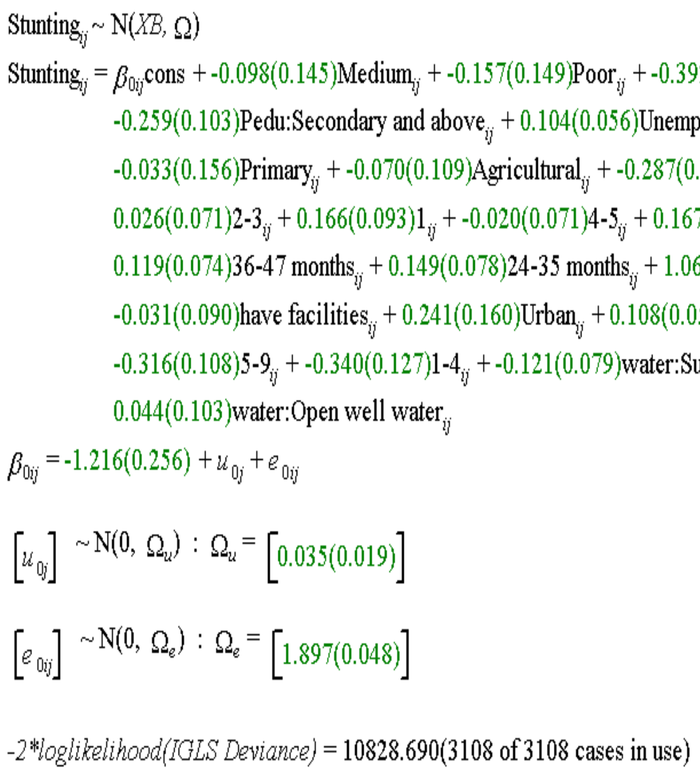
$$\begin{aligned} \text{Stunting}_{ij} = \beta_{0ij}\text{cons} &+ 0.106(0.039)\text{Water}_{ij} + 0.151(0.047)\text{Pedu}_{ij} + -0.107(0.058)\text{Memploy}_{ij} + 0.095(0.061)\text{Medu}_{ij} + \\ &0.094(0.114)\text{Pemploy}_{ij} + -0.408(0.072)\text{Diahrea}_{ij} + 0.058(0.072)\text{Fever}_{ij} + -0.051(0.029)\text{BORD}_{ij} + \\ &-0.277(0.017)\text{Aochild}_{ij} + 0.003(0.093)\text{Tiolot}_{ij} + 0.381(0.152)\text{Plread}_{ij} + -0.119(0.051)\text{Sexoch}_{ij} + \\ &-0.115(0.079)\text{Sexhd}_{ij} + 0.118(0.060)\text{HHmem}_{ij} + 0.079(0.054)\text{Windex}_{ij} \end{aligned}$$

$$\beta_{0ij} = -1.008(0.142) + u_{0j} + e_{0ij}$$

$$\begin{bmatrix} u_{0j} \end{bmatrix} \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \begin{bmatrix} 0.124(0.027) \end{bmatrix}$$

$$\begin{bmatrix} e_{0ij} \end{bmatrix} \sim \text{N}(0,\ \Omega_e)\ :\ \Omega_e = \begin{bmatrix} 1.905(0.051) \end{bmatrix}$$

*-2*loglikelihood(IGLS Deviance)* = 10979.660(3108 of 3108 cases in use)



$$\text{Stunting}_{ij} \sim \text{N}(XB,\ \Omega)$$

$$\begin{aligned}\text{Stunting}_{ij} = {} & \beta_{0ij}\text{cons} + \text{-}0.098(0.145)\text{Medium}_{ij} + \text{-}0.157(0.149)\text{Poor}_{ij} + \text{-}0.392(0.106)\text{Pedu:Primary}_{ij} + \\ & \text{-}0.259(0.103)\text{Pedu:Secondary and above}_{ij} + 0.104(0.056)\text{Unempled}_{ij} + \text{-}0.165(0.157)\text{No education}_{ij} + \\ & \text{-}0.033(0.156)\text{Primary}_{ij} + \text{-}0.070(0.109)\text{Agricultural}_{ij} + \text{-}0.287(0.071)\text{Diahrea:yes}_{ij} + 0.081(0.070)\text{Yes}_{ij} + \\ & 0.026(0.071)\text{2-3}_{ij} + 0.166(0.093)\text{1}_{ij} + \text{-}0.020(0.071)\text{4-5}_{ij} + 0.167(0.079)\text{12-23 months}_{ij} + \\ & 0.119(0.074)\text{36-47 months}_{ij} + 0.149(0.078)\text{24-35 months}_{ij} + 1.063(0.103)\text{6-11 months}_{ij} + 1.839(0.104)\text{<6 months}_{ij} + \\ & \text{-}0.031(0.090)\text{have facilities}_{ij} + 0.241(0.160)\text{Urban}_{ij} + 0.108(0.050)\text{SOchild:Female}_{ij} + 0.129(0.076)\text{Female}_{ij} + \\ & \text{-}0.316(0.108)\text{5-9}_{ij} + \text{-}0.340(0.127)\text{1-4}_{ij} + \text{-}0.121(0.079)\text{water:Surface water}_{ij} + \\ & 0.044(0.103)\text{water:Open well water}_{ij}\end{aligned}$$

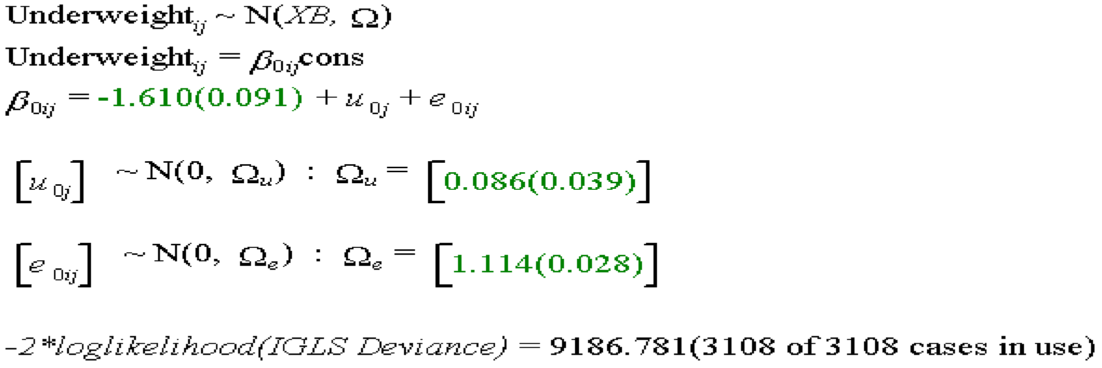
$$\beta_{0ij} = \text{-}1.216(0.256) + u_{0j} + e_{0ij}$$

$$\begin{bmatrix} u_{0j} \end{bmatrix} \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \begin{bmatrix} 0.035(0.019) \end{bmatrix}$$

$$\begin{bmatrix} e_{0ij} \end{bmatrix} \sim \text{N}(0,\ \Omega_e)\ :\ \Omega_e = \begin{bmatrix} 1.897(0.048) \end{bmatrix}$$

*-2*loglikelihood(IGLS Deviance)* = 10828.690(3108 of 3108 cases in use)

Empty model for underweight with random effect



$$\text{Underweight}_{ij} \sim \text{N}(XB,\ \Omega)$$

$$\text{Underweight}_{ij} = \beta_{0ij}\text{cons}$$

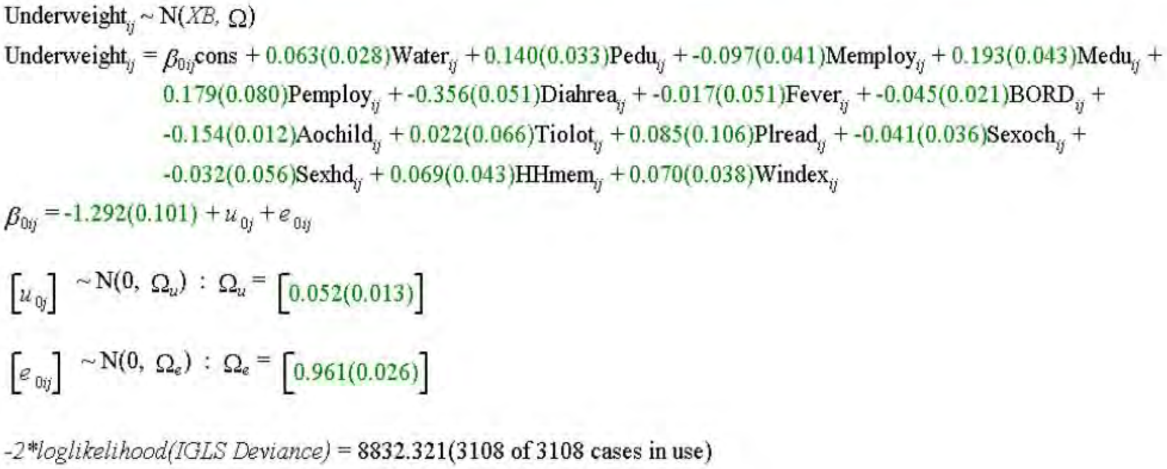
$$\beta_{0ij} = \text{-}1.610(0.091) + u_{0j} + e_{0ij}$$

$$\begin{bmatrix} u_{0j} \end{bmatrix} \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \begin{bmatrix} 0.086(0.039) \end{bmatrix}$$

$$\begin{bmatrix} e_{0ij} \end{bmatrix} \sim \text{N}(0,\ \Omega_e)\ :\ \Omega_e = \begin{bmatrix} 1.114(0.028) \end{bmatrix}$$

*-2*loglikelihood(IGLS Deviance)* = 9186.781(3108 of 3108 cases in use)

Random intercept model for underweight



$$\text{Underweight}_{ij} \sim \text{N}(XB,\ \Omega)$$

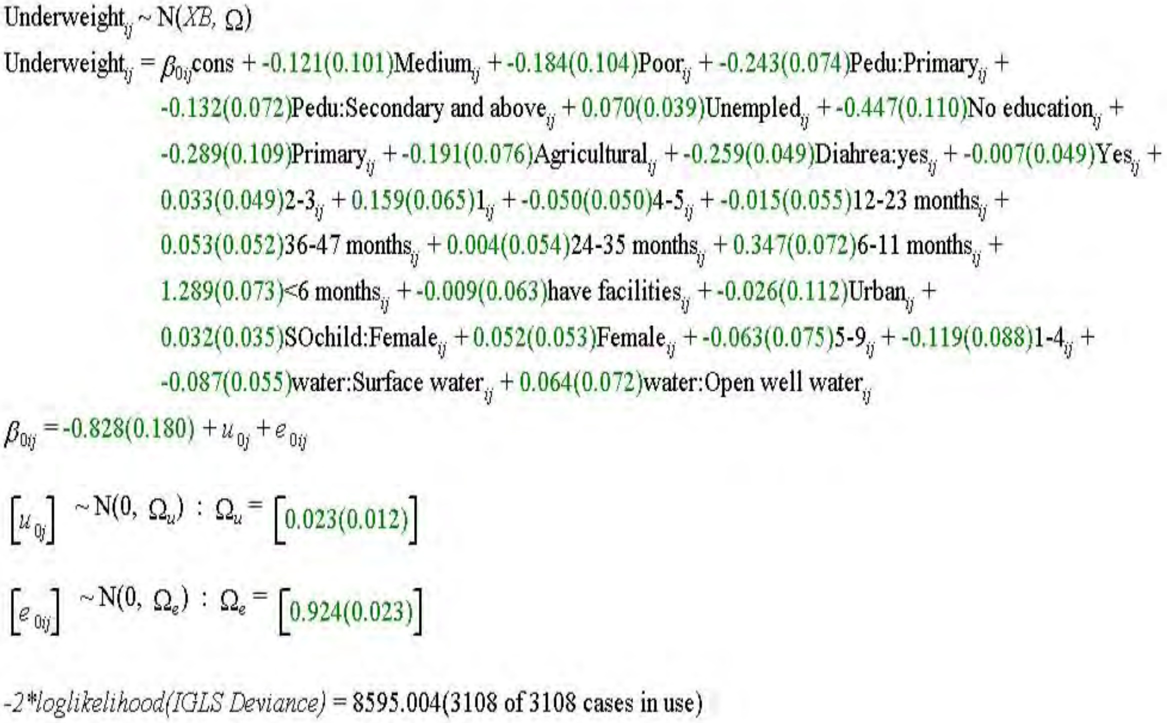
$$\begin{aligned}\text{Underweight}_{ij} = {} & \beta_{0ij}\text{cons} + 0.063(0.028)\text{Water}_{ij} + 0.140(0.033)\text{Pedu}_{ij} + -0.097(0.041)\text{Memploy}_{ij} + 0.193(0.043)\text{Medu}_{ij} + \\ & 0.179(0.080)\text{Pemploy}_{ij} + -0.356(0.051)\text{Diahrea}_{ij} + -0.017(0.051)\text{Fever}_{ij} + -0.045(0.021)\text{BORD}_{ij} + \\ & -0.154(0.012)\text{Aochild}_{ij} + 0.022(0.066)\text{Tiolot}_{ij} + 0.085(0.106)\text{Plread}_{ij} + -0.041(0.036)\text{Sexoch}_{ij} + \\ & -0.032(0.056)\text{Sexhd}_{ij} + 0.069(0.043)\text{HHmem}_{ij} + 0.070(0.038)\text{Windex}_{ij}\end{aligned}$$

$$\beta_{0ij} = -1.292(0.101) + u_{0j} + e_{0ij}$$

$$\left[u_{0j}\right] \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \left[0.052(0.013)\right]$$

$$\left[e_{0ij}\right] \sim \text{N}(0,\ \Omega_e)\ :\ \Omega_e = \left[0.961(0.026)\right]$$

*-2*loglikelihood(IGLS Deviance)* = 8832.321(3108 of 3108 cases in use)



$$\text{Underweight}_{ij} \sim \text{N}(XB,\ \Omega)$$

$$\begin{aligned}\text{Underweight}_{ij} = {} & \beta_{0ij}\text{cons} + -0.121(0.101)\text{Medium}_{ij} + -0.184(0.104)\text{Poor}_{ij} + -0.243(0.074)\text{Pedu:Primary}_{ij} + \\ & -0.132(0.072)\text{Pedu:Secondary and above}_{ij} + 0.070(0.039)\text{Unempled}_{ij} + -0.447(0.110)\text{No education}_{ij} + \\ & -0.289(0.109)\text{Primary}_{ij} + -0.191(0.076)\text{Agricultural}_{ij} + -0.259(0.049)\text{Diahrea:yes}_{ij} + -0.007(0.049)\text{Yes}_{ij} + \\ & 0.033(0.049)\text{2-3}_{ij} + 0.159(0.065)\text{1}_{ij} + -0.050(0.050)\text{4-5}_{ij} + -0.015(0.055)\text{12-23 months}_{ij} + \\ & 0.053(0.052)\text{36-47 months}_{ij} + 0.004(0.054)\text{24-35 months}_{ij} + 0.347(0.072)\text{6-11 months}_{ij} + \\ & 1.289(0.073)\text{<6 months}_{ij} + -0.009(0.063)\text{have facilities}_{ij} + -0.026(0.112)\text{Urban}_{ij} + \\ & 0.032(0.035)\text{SOchild:Female}_{ij} + 0.052(0.053)\text{Female}_{ij} + -0.063(0.075)\text{5-9}_{ij} + -0.119(0.088)\text{1-4}_{ij} + \\ & -0.087(0.055)\text{water:Surface water}_{ij} + 0.064(0.072)\text{water:Open well water}_{ij}\end{aligned}$$

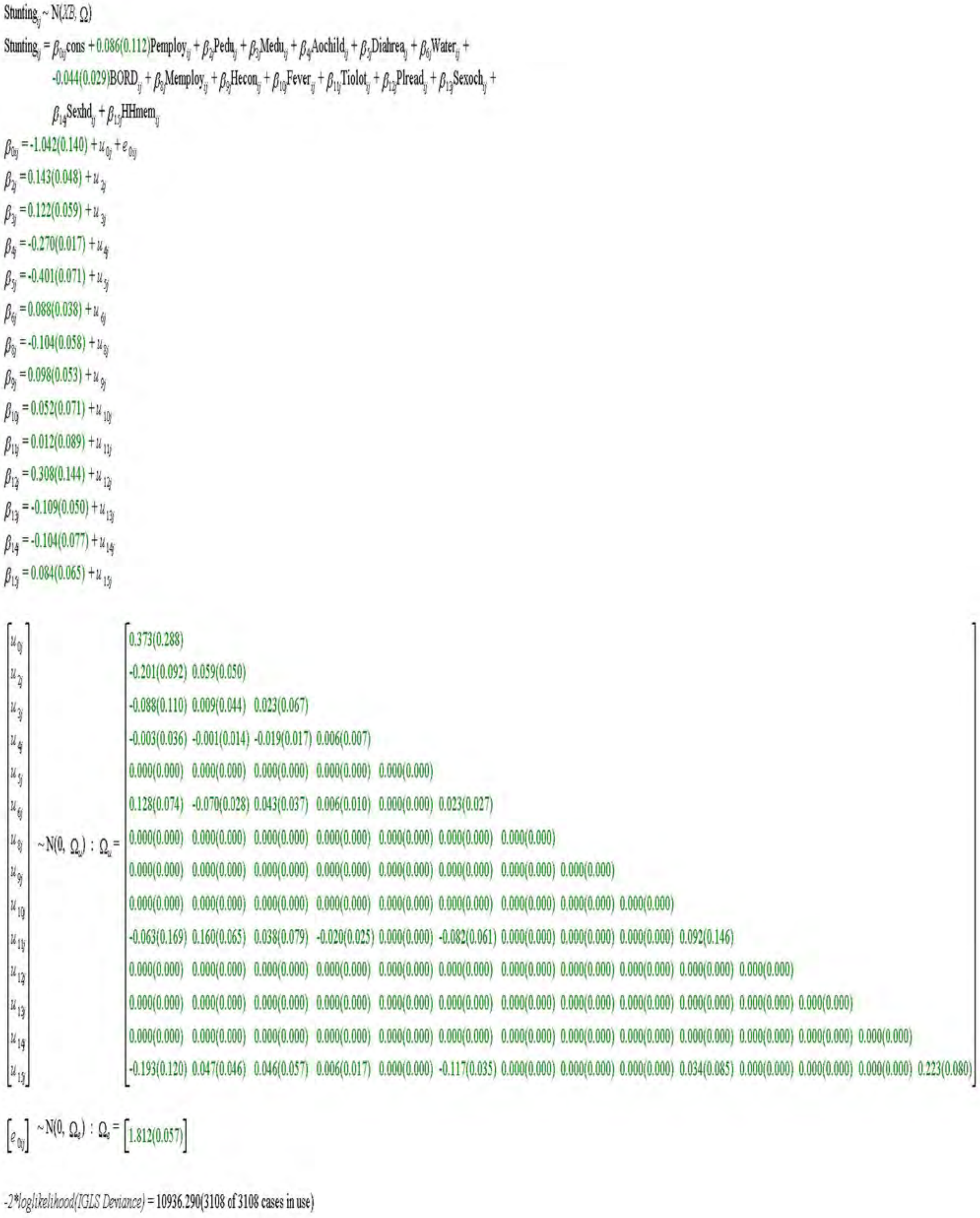
$$\beta_{0ij} = -0.828(0.180) + u_{0j} + e_{0ij}$$

$$\left[u_{0j}\right] \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \left[0.023(0.012)\right]$$

$$\left[e_{0ij}\right] \sim \text{N}(0,\ \Omega_e)\ :\ \Omega_e = \left[0.924(0.023)\right]$$

*-2*loglikelihood(IGLS Deviance)* = 8595.004(3108 of 3108 cases in use)

Random coefficient model for stunting



$$\mathrm{Stunting}_{ij} \sim \mathrm{N}(XB, \Omega)$$

$$\begin{aligned}\mathrm{Stunting}_{ij} = {} & \beta_{0ij}\mathrm{cons} + 0.086(0.112)\mathrm{Pemploy}_{ij} + \beta_{2j}\mathrm{Pedu}_{ij} + \beta_{3j}\mathrm{Medu}_{ij} + \beta_{4j}\mathrm{Aochild}_{ij} + \beta_{5j}\mathrm{Diahrea}_{ij} + \beta_{6j}\mathrm{Water}_{ij} + \\ & -0.044(0.029)\mathrm{BORD}_{ij} + \beta_{8j}\mathrm{Memploy}_{ij} + \beta_{9j}\mathrm{Hecon}_{ij} + \beta_{10j}\mathrm{Fever}_{ij} + \beta_{11j}\mathrm{Tiolot}_{ij} + \beta_{12j}\mathrm{Plread}_{ij} + \beta_{13j}\mathrm{Sexoch}_{ij} + \\ & \beta_{14j}\mathrm{Sexhd}_{ij} + \beta_{15j}\mathrm{HHmem}_{ij}\end{aligned}$$

$$\beta_{0ij} = -1.042(0.140) + u_{0j} + e_{0ij}$$

$$\beta_{2j} = 0.143(0.048) + u_{2j}$$

$$\beta_{3j} = 0.122(0.059) + u_{3j}$$

$$\beta_{4j} = -0.270(0.017) + u_{4j}$$

$$\beta_{5j} = -0.401(0.071) + u_{5j}$$

$$\beta_{6j} = 0.088(0.038) + u_{6j}$$

$$\beta_{8j} = -0.104(0.058) + u_{8j}$$

$$\beta_{9j} = 0.098(0.053) + u_{9j}$$

$$\beta_{10j} = 0.052(0.071) + u_{10j}$$

$$\beta_{11j} = 0.012(0.089) + u_{11j}$$

$$\beta_{12j} = 0.308(0.144) + u_{12j}$$

$$\beta_{13j} = -0.109(0.050) + u_{13j}$$

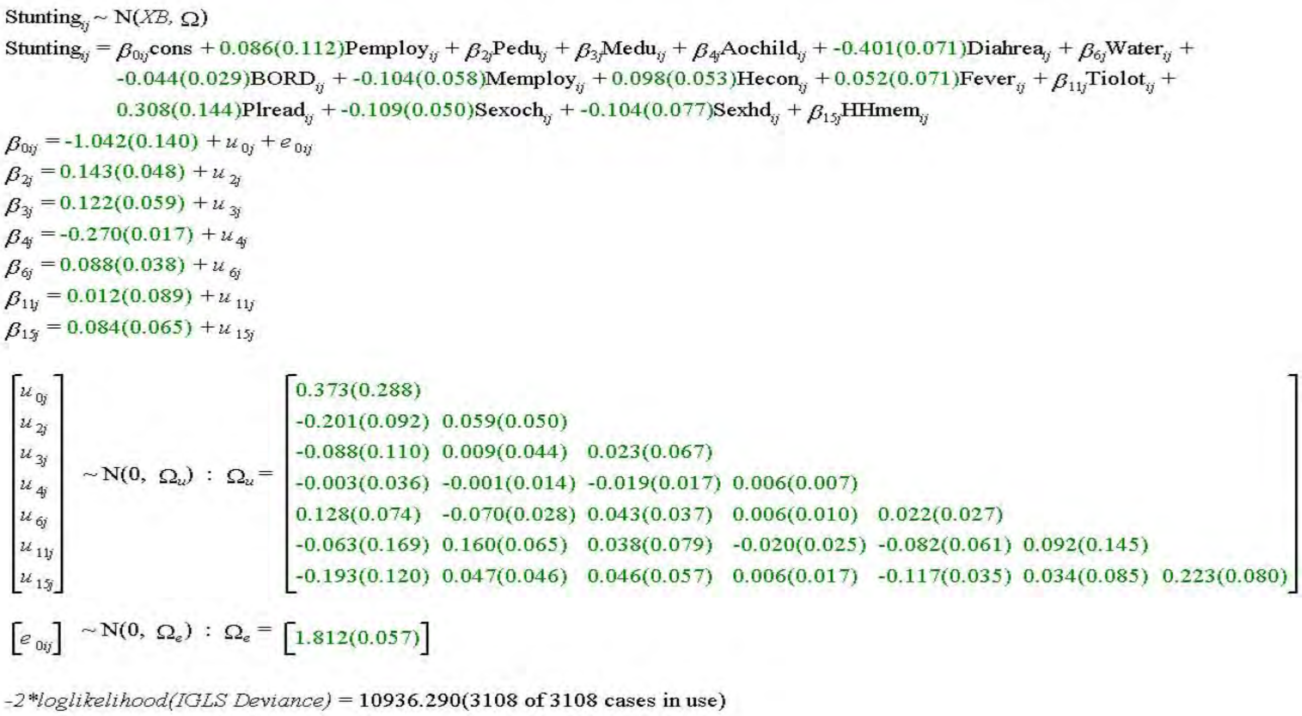
$$\beta_{14j} = -0.104(0.077) + u_{14j}$$

$$\beta_{15j} = 0.084(0.065) + u_{15j}$$

$$\begin{bmatrix} u_{0j} \\ u_{2j} \\ u_{3j} \\ u_{4j} \\ u_{5j} \\ u_{6j} \\ u_{8j} \\ u_{9j} \\ u_{10j} \\ u_{11j} \\ u_{12j} \\ u_{13j} \\ u_{14j} \\ u_{15j} \end{bmatrix} \sim \mathrm{N}(0, \Omega_u) : \Omega_u = \begin{bmatrix} 0.373(0.288) \\ -0.201(0.092) & 0.059(0.050) \\ -0.088(0.110) & 0.009(0.044) & 0.023(0.067) \\ -0.003(0.036) & -0.001(0.014) & -0.019(0.017) & 0.006(0.007) \\ 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) \\ 0.128(0.074) & -0.070(0.028) & 0.043(0.037) & 0.006(0.010) & 0.000(0.000) & 0.023(0.027) \\ 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) \\ 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) \\ 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) \\ -0.063(0.169) & 0.160(0.065) & 0.038(0.079) & -0.020(0.025) & 0.000(0.000) & -0.082(0.061) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.092(0.146) \\ 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) \\ 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) \\ 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) \\ -0.193(0.120) & 0.047(0.046) & 0.046(0.057) & 0.006(0.017) & 0.000(0.000) & -0.117(0.035) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.034(0.085) & 0.000(0.000) & 0.000(0.000) & 0.000(0.000) & 0.223(0.080) \end{bmatrix}$$

$$\begin{bmatrix} e_{0ij} \end{bmatrix} \sim \mathrm{N}(0, \Omega_e) : \Omega_e = \begin{bmatrix} 1.812(0.057) \end{bmatrix}$$

*-2*loglikelihood(IGLS Deviance)* = 10936.290(3108 of 3108 cases in use)



$$\text{Stunting}_{ij} \sim \text{N}(XB,\ \Omega)$$

$$\begin{aligned}\text{Stunting}_{ij} = {} & \beta_{0ij}\text{cons} + 0.086(0.112)\text{Pemploy}_{ij} + \beta_{2j}\text{Pedu}_{ij} + \beta_{3j}\text{Medu}_{ij} + \beta_{4j}\text{Aochild}_{ij} + -0.401(0.071)\text{Diahrea}_{ij} + \beta_{6j}\text{Water}_{ij} + {} \\ & -0.044(0.029)\text{BORD}_{ij} + -0.104(0.058)\text{Memploy}_{ij} + 0.098(0.053)\text{Hecon}_{ij} + 0.052(0.071)\text{Fever}_{ij} + \beta_{11j}\text{Tiolot}_{ij} + {} \\ & 0.308(0.144)\text{Plread}_{ij} + -0.109(0.050)\text{Sexoch}_{ij} + -0.104(0.077)\text{Sexhd}_{ij} + \beta_{15j}\text{HHmem}_{ij}\end{aligned}$$

$$\beta_{0ij} = -1.042(0.140) + u_{0j} + e_{0ij}$$

$$\beta_{2j} = 0.143(0.048) + u_{2j}$$

$$\beta_{3j} = 0.122(0.059) + u_{3j}$$

$$\beta_{4j} = -0.270(0.017) + u_{4j}$$

$$\beta_{6j} = 0.088(0.038) + u_{6j}$$

$$\beta_{11j} = 0.012(0.089) + u_{11j}$$

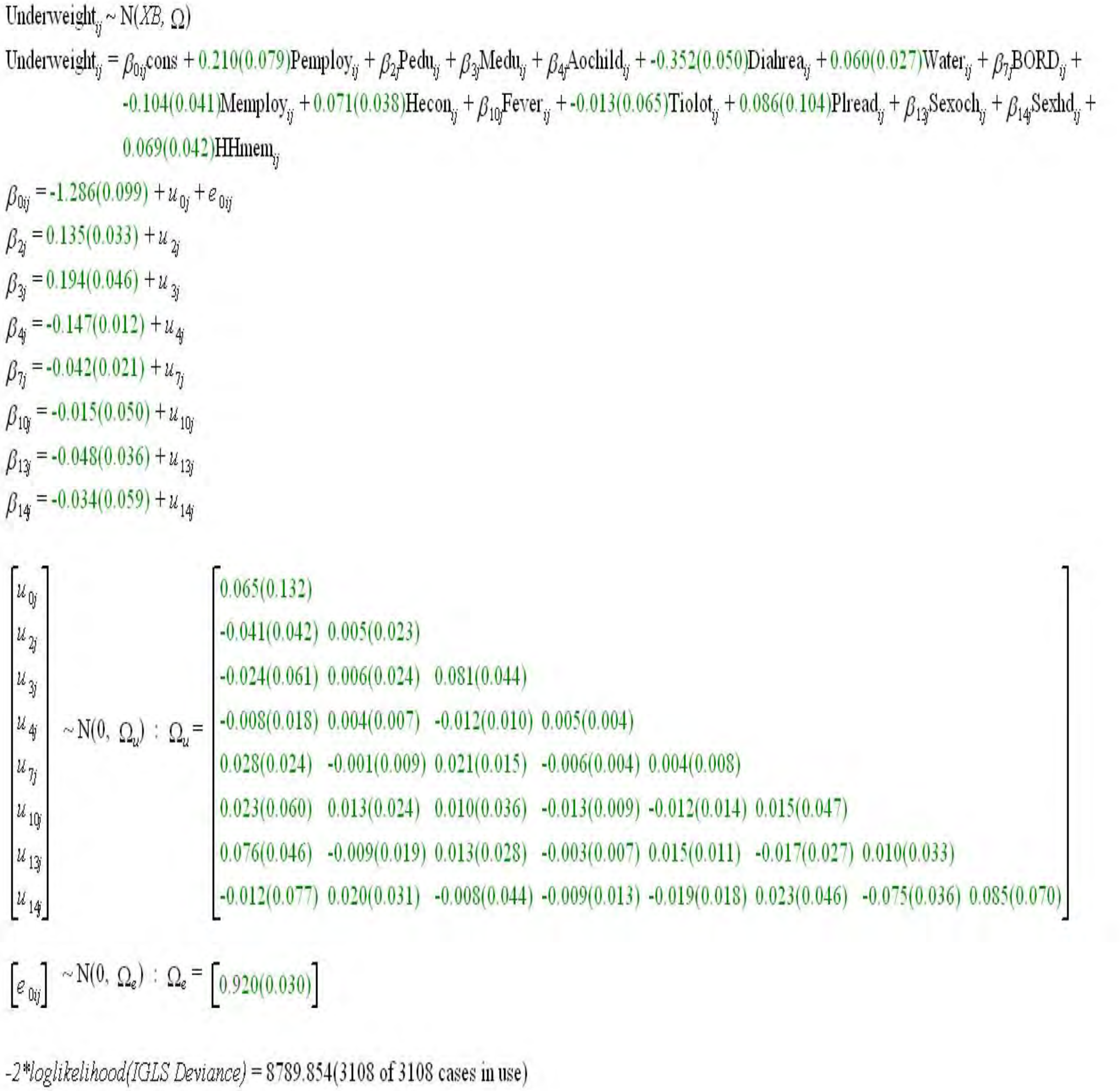
$$\beta_{15j} = 0.084(0.065) + u_{15j}$$

$$\begin{bmatrix} u_{0j} \\ u_{2j} \\ u_{3j} \\ u_{4j} \\ u_{6j} \\ u_{11j} \\ u_{15j} \end{bmatrix} \sim \text{N}(0,\ \Omega_u) \ : \ \Omega_u = \begin{bmatrix} 0.373(0.288) & & & & & & \\ -0.201(0.092) & 0.059(0.050) & & & & & \\ -0.088(0.110) & 0.009(0.044) & 0.023(0.067) & & & & \\ -0.003(0.036) & -0.001(0.014) & -0.019(0.017) & 0.006(0.007) & & & \\ 0.128(0.074) & -0.070(0.028) & 0.043(0.037) & 0.006(0.010) & 0.022(0.027) & & \\ -0.063(0.169) & 0.160(0.065) & 0.038(0.079) & -0.020(0.025) & -0.082(0.061) & 0.092(0.145) & \\ -0.193(0.120) & 0.047(0.046) & 0.046(0.057) & 0.006(0.017) & -0.117(0.035) & 0.034(0.085) & 0.223(0.080) \end{bmatrix}$$

$$\begin{bmatrix} e_{0ij} \end{bmatrix} \sim \text{N}(0,\ \Omega_e) \ : \ \Omega_e = \begin{bmatrix} 1.812(0.057) \end{bmatrix}$$

*-2*loglikelihood(IGLS Deviance)* = **10936.290(3108 of 3108 cases in use)**

Random coefficient model for underweight



$$\text{Underweight}_{ij} \sim \mathrm{N}(XB,\ \Omega)$$

$$\begin{aligned}\text{Underweight}_{ij} = {} & \beta_{0ij}\text{cons} + 0.210(0.079)\text{Pemploy}_{ij} + \beta_{2j}\text{Pedu}_{ij} + \beta_{3j}\text{Medu}_{ij} + \beta_{4j}\text{Aochild}_{ij} + -0.352(0.050)\text{Diahrea}_{ij} + 0.060(0.027)\text{Water}_{ij} + \beta_{7j}\text{BORD}_{ij} + \\ & -0.104(0.041)\text{Memploy}_{ij} + 0.071(0.038)\text{Hecon}_{ij} + \beta_{10j}\text{Fever}_{ij} + -0.013(0.065)\text{Tiolot}_{ij} + 0.086(0.104)\text{Plread}_{ij} + \beta_{13j}\text{Sexoch}_{ij} + \beta_{14j}\text{Sexhd}_{ij} + \\ & 0.069(0.042)\text{HHmem}_{ij}\end{aligned}$$

$$\beta_{0ij} = -1.286(0.099) + u_{0j} + e_{0ij}$$

$$\beta_{2j} = 0.135(0.033) + u_{2j}$$

$$\beta_{3j} = 0.194(0.046) + u_{3j}$$

$$\beta_{4j} = -0.147(0.012) + u_{4j}$$

$$\beta_{7j} = -0.042(0.021) + u_{7j}$$

$$\beta_{10j} = -0.015(0.050) + u_{10j}$$

$$\beta_{13j} = -0.048(0.036) + u_{13j}$$

$$\beta_{14j} = -0.034(0.059) + u_{14j}$$

$$\begin{bmatrix} u_{0j} \\ u_{2j} \\ u_{3j} \\ u_{4j} \\ u_{7j} \\ u_{10j} \\ u_{13j} \\ u_{14j} \end{bmatrix} \sim \mathrm{N}(0,\ \Omega_u)\ :\ \Omega_u = \begin{bmatrix} 0.065(0.132) & & & & & & & \\ -0.041(0.042) & 0.005(0.023) & & & & & & \\ -0.024(0.061) & 0.006(0.024) & 0.081(0.044) & & & & & \\ -0.008(0.018) & 0.004(0.007) & -0.012(0.010) & 0.005(0.004) & & & & \\ 0.028(0.024) & -0.001(0.009) & 0.021(0.015) & -0.006(0.004) & 0.004(0.008) & & & \\ 0.023(0.060) & 0.013(0.024) & 0.010(0.036) & -0.013(0.009) & -0.012(0.014) & 0.015(0.047) & & \\ 0.076(0.046) & -0.009(0.019) & 0.013(0.028) & -0.003(0.007) & 0.015(0.011) & -0.017(0.027) & 0.010(0.033) & \\ -0.012(0.077) & 0.020(0.031) & -0.008(0.044) & -0.009(0.013) & -0.019(0.018) & 0.023(0.046) & -0.075(0.036) & 0.085(0.070) \end{bmatrix}$$

$$\begin{bmatrix} e_{0ij} \end{bmatrix} \sim \mathrm{N}(0,\ \Omega_e)\ :\ \Omega_e = \begin{bmatrix} 0.920(0.030) \end{bmatrix}$$

*-2*loglikelihood(IGLS Deviance)* = 8789.854(3108 of 3108 cases in use)

Multivariate empty model without level 2 random effect

$$\text{resp}_{1j} \sim \text{N}(XB,\ \Omega)$$

$$\text{resp}_{2j} \sim \text{N}(XB,\ \Omega)$$

$$\text{resp}_{1j} = \beta_{0j}\text{cons.Stunting}_{ij}$$

$$\beta_{0j} = -1.845(0.027) + u_{0j}$$

$$\text{resp}_{2j} = \beta_{1j}\text{cons.Underweight}_{ij}$$

$$\beta_{1j} = -1.683(0.019) + u_{1j}$$

$$\begin{bmatrix} u_{0j} \\ u_{1j} \end{bmatrix} \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \begin{bmatrix} 2.314(0.059) & \\ 1.216(0.037) & 1.167(0.030) \end{bmatrix}$$

$-2*loglikelihood(IGLS\ Deviance)$ = 18260.890(6216 of 6216 cases in use)

Multivariate empty model with level 2 random effect

$$\text{resp}_{1jk} \sim \text{N}(XB,\ \Omega)$$

$$\text{resp}_{2jk} \sim \text{N}(XB,\ \Omega)$$

$$\text{resp}_{1jk} = \beta_{0jk}\text{cons.Stunting}_{ijk}$$

$$\beta_{0jk} = -1.709(0.105) + v_{0k} + u_{0jk}$$

$$\text{resp}_{2jk} = \beta_{1jk}\text{cons.Underweight}_{ijk}$$

$$\beta_{1jk} = -1.611(0.091) + v_{1k} + u_{1jk}$$

$$\begin{bmatrix} v_{0k} \\ v_{1k} \end{bmatrix} \sim \text{N}(0,\ \Omega_v)\ :\ \Omega_v = \begin{bmatrix} 0.110(0.051) & \\ 0.085(0.042) & 0.086(0.039) \end{bmatrix}$$

$$\begin{bmatrix} u_{0jk} \\ u_{1jk} \end{bmatrix} \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \begin{bmatrix} 2.242(0.057) & \\ 1.168(0.035) & 1.114(0.028) \end{bmatrix}$$

$-2*loglikelihood(IGLS\ Deviance)$ = 18080.420(6216 of 6216 cases in use)

Multivariate random intercept model

$$\text{resp}_{1ijk} \sim \text{N}(XB,\ \Omega)$$

$$\text{resp}_{2ijk} \sim \text{N}(XB,\ \Omega)$$

$$\begin{aligned}
\text{resp}_{1ijk} = {} & \beta_{0ijk}\text{cons.Stunting}_{ijk} + -0.119(0.080)\text{Surface water.Stunting}_{ijk} + 0.048(0.103)\text{Open well water.Stunting}_{ijk} + -0.116(0.145)\text{Poor.Stunting}_{ijk} + \\
& -0.193(0.149)\text{Very poor.Stunting}_{ijk} + -0.075(0.112)\text{1-4.Stunting}_{ijk} + -0.122(0.104)\text{5-9.Stunting}_{ijk} + -0.392(0.106)\text{No education.Stunting}_{ijk} + \\
& -0.257(0.103)\text{Primary.Stunting}_{ijk} + 0.103(0.056)\text{Unempled.Stunting}_{ijk} + -0.153(0.158)\text{no educationm.Stunting}_{ijk} + \\
& -0.024(0.156)\text{primarym.Stunting}_{ijk} + -0.067(0.109)\text{Agricultural.Stunting}_{ijk} + -0.288(0.071)\text{yes.Stunting}_{ijk} + 0.081(0.071)\text{yesf.Stunting}_{ijk} + \\
& -0.028(0.066)\text{2-3.Stunting}_{ijk} + 0.100(0.080)\text{1.Stunting}_{ijk} + -0.071(0.069)\text{4-5.Stunting}_{ijk} + 0.163(0.079)\text{12-23 months.Stunting}_{ijk} + \\
& 0.125(0.074)\text{36-47 months.Stunting}_{ijk} + 0.151(0.078)\text{24-35 months.Stunting}_{ijk} + 1.064(0.103)\text{6-11 months.Stunting}_{ijk} + \\
& 1.834(0.104)\text{<6 months.Stunting}_{ijk} + 0.228(0.160)\text{Urban.Stunting}_{ijk} + 0.109(0.050)\text{FEmale.Stunting}_{ijk} + 0.119(0.076)\text{femaleh.Stunting}_{ijk} + \\
& -0.038(0.090)\text{have facilities.Stunting}_{ijk}
\end{aligned}$$

$$\beta_{0ijk} = -1.352(0.266) + v_{0k} + u_{0ijk}$$

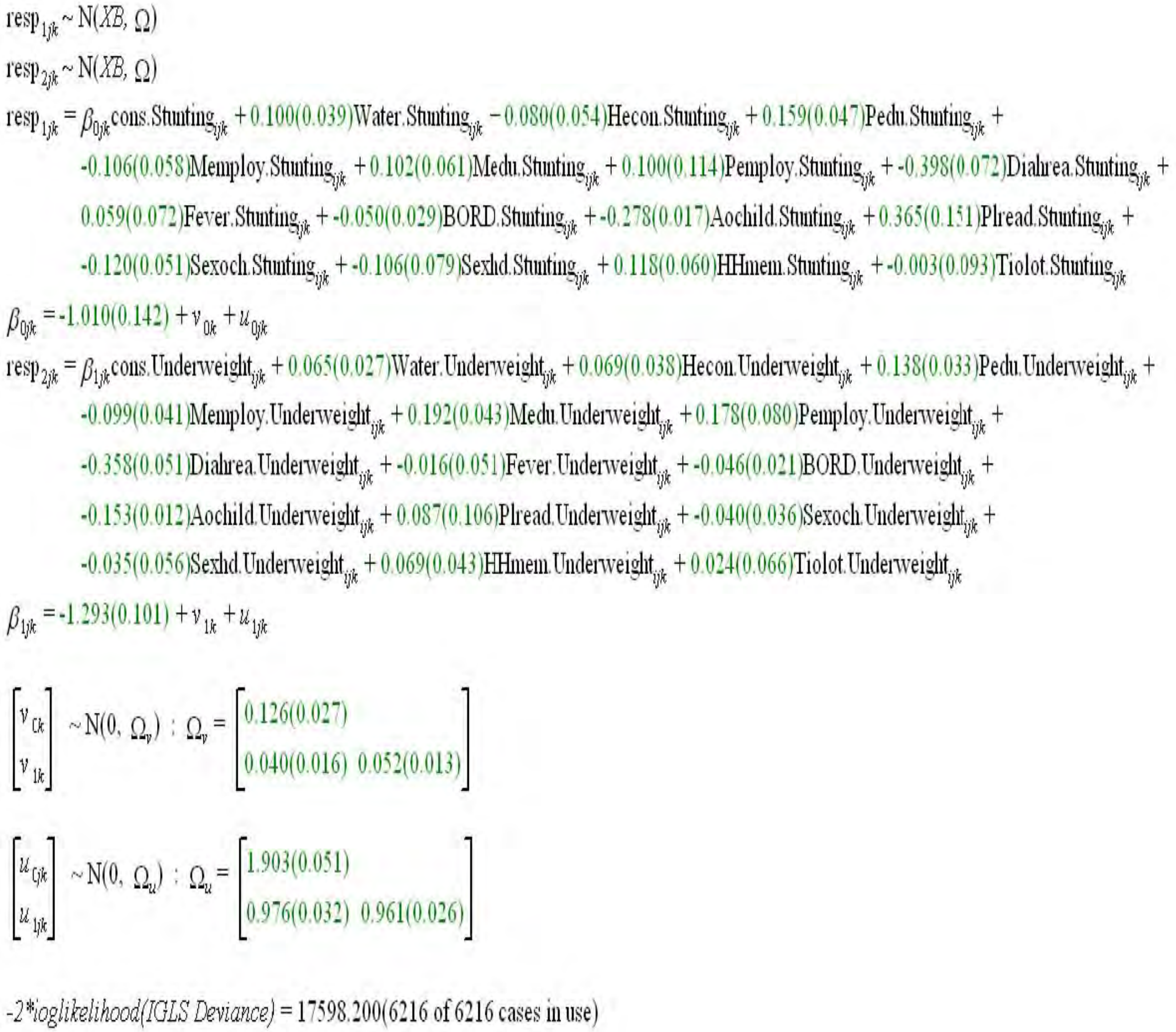
$$\begin{aligned}
\text{resp}_{2ijk} = {} & \beta_{1ijk}\text{cons.Underweight}_{ijk} + -0.092(0.055)\text{Surface water.Underweight}_{ijk} + 0.062(0.072)\text{Open well water.Underweight}_{ijk} + \\
& -0.125(0.101)\text{Poor.Underweight}_{ijk} + -0.195(0.104)\text{Very poor.Underweight}_{ijk} + -0.076(0.078)\text{1-4.Underweight}_{ijk} + \\
& -0.079(0.072)\text{5-9.Underweight}_{ijk} + -0.241(0.074)\text{No education.Underweight}_{ijk} + -0.130(0.072)\text{Primary.Underweight}_{ijk} + \\
& 0.071(0.039)\text{Unempled.Underweight}_{ijk} + -0.452(0.110)\text{no educationm.Underweight}_{ijk} + -0.298(0.108)\text{primarym.Underweight}_{ijk} + \\
& -0.192(0.076)\text{Agricultural.Underweight}_{ijk} + -0.261(0.049)\text{yes.Underweight}_{ijk} + -0.008(0.049)\text{yesf.Underweight}_{ijk} + \\
& 0.007(0.046)\text{2-3.Underweight}_{ijk} + 0.114(0.056)\text{1.Underweight}_{ijk} + -0.061(0.048)\text{4-5.Underweight}_{ijk} + \\
& -0.021(0.055)\text{12-23 months.Underweight}_{ijk} + 0.053(0.052)\text{36-47 months.Underweight}_{ijk} + 0.000(0.054)\text{24-35 months.Underweight}_{ijk} + \\
& 0.341(0.072)\text{6-11 months.Underweight}_{ijk} + 1.283(0.073)\text{<6 months.Underweight}_{ijk} + -0.035(0.112)\text{Urban.Underweight}_{ijk} + \\
& 0.033(0.035)\text{FEmale.Underweight}_{ijk} + 0.047(0.053)\text{femaleh.Underweight}_{ijk} + -0.010(0.063)\text{have facilities.Underweight}_{ijk}
\end{aligned}$$

$$\beta_{1ijk} = -0.791(0.187) + v_{1k} + u_{1ijk}$$

$$\begin{bmatrix} v_{0k} \\ v_{1k} \end{bmatrix} \sim \text{N}(0,\ \Omega_v)\ :\ \Omega_v = \begin{bmatrix} 0.036(0.019) & \\ 0.016(0.012) & 0.023(0.012) \end{bmatrix}$$

$$\begin{bmatrix} u_{0ijk} \\ u_{1ijk} \end{bmatrix} \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \begin{bmatrix} 1.901(0.048) & \\ 0.929(0.029) & 0.924(0.023) \end{bmatrix}$$

*-2*loglikelihood(IGLS Deviance)* = 17330.950(6216 of 6216 cases in use)



$$\text{resp}_{1jk} \sim \text{N}(XB,\ \Omega)$$

$$\text{resp}_{2jk} \sim \text{N}(XB,\ \Omega)$$

$$\begin{aligned}\text{resp}_{1jk} = {} & \beta_{0jk}\text{cons.Stunting}_{ijk} + 0.100(0.039)\text{Water.Stunting}_{ijk} - 0.080(0.054)\text{Hecon.Stunting}_{ijk} + 0.159(0.047)\text{Pedu.Stunting}_{ijk} + \\ & \text{-}0.106(0.058)\text{Memploy.Stunting}_{ijk} + 0.102(0.061)\text{Medu.Stunting}_{ijk} + 0.100(0.114)\text{Pemploy.Stunting}_{ijk} + \text{-}0.398(0.072)\text{Diahrea.Stunting}_{ijk} + \\ & 0.059(0.072)\text{Fever.Stunting}_{ijk} + \text{-}0.050(0.029)\text{BORD.Stunting}_{ijk} + \text{-}0.278(0.017)\text{Aochild.Stunting}_{ijk} + 0.365(0.151)\text{Plread.Stunting}_{ijk} + \\ & \text{-}0.120(0.051)\text{Sexoch.Stunting}_{ijk} + \text{-}0.106(0.079)\text{Sexhd.Stunting}_{ijk} + 0.118(0.060)\text{HHmem.Stunting}_{ijk} + \text{-}0.003(0.093)\text{Tiolot.Stunting}_{ijk}\end{aligned}$$

$$\beta_{0jk} = \text{-}1.010(0.142) + v_{0k} + u_{0jk}$$

$$\begin{aligned}\text{resp}_{2jk} = {} & \beta_{1jk}\text{cons.Underweight}_{ijk} + 0.065(0.027)\text{Water.Underweight}_{ijk} + 0.069(0.038)\text{Hecon.Underweight}_{ijk} + 0.138(0.033)\text{Pedu.Underweight}_{ijk} + \\ & \text{-}0.099(0.041)\text{Memploy.Underweight}_{ijk} + 0.192(0.043)\text{Medu.Underweight}_{ijk} + 0.178(0.080)\text{Pemploy.Underweight}_{ijk} + \\ & \text{-}0.358(0.051)\text{Diahrea.Underweight}_{ijk} + \text{-}0.016(0.051)\text{Fever.Underweight}_{ijk} + \text{-}0.046(0.021)\text{BORD.Underweight}_{ijk} + \\ & \text{-}0.153(0.012)\text{Aochild.Underweight}_{ijk} + 0.087(0.106)\text{Plread.Underweight}_{ijk} + \text{-}0.040(0.036)\text{Sexoch.Underweight}_{ijk} + \\ & \text{-}0.035(0.056)\text{Sexhd.Underweight}_{ijk} + 0.069(0.043)\text{HHmem.Underweight}_{ijk} + 0.024(0.066)\text{Tiolot.Underweight}_{ijk}\end{aligned}$$

$$\beta_{1jk} = \text{-}1.293(0.101) + v_{1k} + u_{1jk}$$

$$\begin{bmatrix} v_{0k} \\ v_{1k} \end{bmatrix} \sim \text{N}(0,\ \Omega_v)\ :\ \Omega_v = \begin{bmatrix} 0.126(0.027) & \\ 0.040(0.016) & 0.052(0.013) \end{bmatrix}$$

$$\begin{bmatrix} u_{0jk} \\ u_{1jk} \end{bmatrix} \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \begin{bmatrix} 1.903(0.051) & \\ 0.976(0.032) & 0.961(0.026) \end{bmatrix}$$

*-2*loglikelihood(IGLS Deviance)* = 17598.200(6216 of 6216 cases in use)

Multivariate random coefficient model

$$\text{resp}_{1jk} \sim \text{N}(XB,\ \Omega)$$

$$\text{resp}_{2jk} \sim \text{N}(XB,\ \Omega)$$

$$\begin{aligned}\text{resp}_{1jk} = {} & \beta_{0jk}\text{cons.Stunting}_{ijk} + 0.090(0.039)\text{Water.Stunting}_{ijk} + 0.078(0.054)\text{Hecon.Stunting}_{ijk} + 0.156(0.047)\text{Pedu.Stunting}_{ijk} + \\ & -0.103(0.058)\text{Memploy.Stunting}_{ijk} + \beta_{10k}\text{Medu.Stunting}_{ijk} + 0.112(0.114)\text{Pemploy.Stunting}_{ijk} + \beta_{14k}\text{Dialrea.Stunting}_{ijk} + \\ & 0.063(0.072)\text{Fever.Stunting}_{ijk} + -0.050(0.029)\text{BORD.Stunting}_{ijk} + \beta_{20k}\text{Aochild.Stunting}_{ijk} + 0.363(0.150)\text{Plread.Stunting}_{ijk} + \\ & -0.120(0.050)\text{Sexoch.Stunting}_{ijk} + -0.098(0.078)\text{Sexhd.Stunting}_{ijk} + 0.118(0.060)\text{HHmem.Stunting}_{ijk} + -0.016(0.093)\text{Tiolot.Stunting}_{ijk}\end{aligned}$$

$$\beta_{0jk} = -1.021(0.142) + v_{0k} + u_{0jk}$$

$$\beta_{10k} = 0.089(0.061) + v_{10k}$$

$$\beta_{14k} = -0.392(0.073) + v_{14k}$$

$$\beta_{20k} = -0.274(0.017) + v_{20k}$$

$$\begin{aligned}\text{resp}_{2jk} = {} & \beta_{1jk}\text{cons.Underweight}_{ijk} + 0.058(0.027)\text{Water.Underweight}_{ijk} + 0.065(0.038)\text{Hecon.Underweight}_{ijk} + 0.140(0.033)\text{Pedu.Underweight}_{ijk} + \\ & -0.092(0.041)\text{Memploy.Underweight}_{ijk} + \beta_{11k}\text{Medu.Underweight}_{ijk} + \beta_{13k}\text{Pemploy.Underweight}_{ijk} + -0.348(0.051)\text{Dialrea.Underweight}_{ijk} + \\ & -0.016(0.051)\text{Fever.Underweight}_{ijk} + -0.044(0.021)\text{BORD.Underweight}_{ijk} + \beta_{21k}\text{Aochild.Underweight}_{ijk} + 0.061(0.104)\text{Plread.Underweight}_{ijk} + \\ & -0.040(0.036)\text{Sexoch.Underweight}_{ijk} + -0.021(0.055)\text{Sexhd.Underweight}_{ijk} + 0.070(0.042)\text{HHmem.Underweight}_{ijk} + \\ & 0.012(0.065)\text{Tiolot.Underweight}_{ijk}\end{aligned}$$

$$\beta_{1jk} = -1.322(0.102) + v_{1k} + u_{1jk}$$

$$\beta_{11k} = 0.176(0.047) + v_{11k}$$

$$\beta_{13k} = 0.211(0.080) + v_{13k}$$

$$\beta_{21k} = -0.148(0.013) + v_{21k}$$

$$\begin{bmatrix} v_{0k} \\ v_{1k} \\ v_{10k} \\ v_{11k} \\ v_{13k} \\ v_{14k} \\ v_{20k} \\ v_{21k} \end{bmatrix} \sim \text{N}(0,\ \Omega_v)\ :\ \Omega_v = \begin{bmatrix} 0.173(0.098) & & & & & & & \\ 0.131(0.066) & 0.213(0.060) & & & & & & \\ -0.040(0.064) & -0.010(0.050) & 0.034(0.053) & & & & & \\ -0.056(0.053) & -0.001(0.040) & 0.072(0.040) & 0.104(0.040) & & & & \\ -0.049(0.053) & -0.079(0.043) & -0.053(0.037) & -0.038(0.030) & 0.057(0.044) & & & \\ -0.047(0.056) & 0.008(0.042) & 0.006(0.046) & 0.024(0.039) & 0.012(0.041) & 0.080(0.055) & & \\ -0.009(0.023) & -0.017(0.017) & -0.003(0.016) & 0.002(0.013) & 0.018(0.014) & 0.004(0.014) & 0.004(0.007) & \\ -0.019(0.016) & -0.034(0.014) & -0.005(0.012) & -0.010(0.010) & 0.017(0.010) & -0.001(0.011) & 0.003(0.004) & 0.006(0.004) \end{bmatrix}$$

$$\begin{bmatrix} u_{0jk} \\ u_{1jk} \end{bmatrix} \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \begin{bmatrix} 1.880(0.054) & \\ 0.957(0.033) & 0.926(0.027) \end{bmatrix}$$

*-2*loglikelihood(IGLS Deviance)* = 17554.740(6216 of 6216 cases in use)

Declaration

I, the undersigned, declare that the thesis is my original work, has not been presented for a degree in any other university and that all sources of material used for the thesis have been duly acknowledged.

Declared by

Name: **BIRHAN FETENE**

Signature: -------------------------------

Date: June 23, 2010

Confirmed by the Advisor

Name: **DR. EMMANUEL G/YOHANNES**

Signature: ---------------------------------

Date: June 23, 2010