Hierarchical Modelling of the Effects of Orphan Status on Child Nutrition in Sub-Saharan Africa

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Abstract

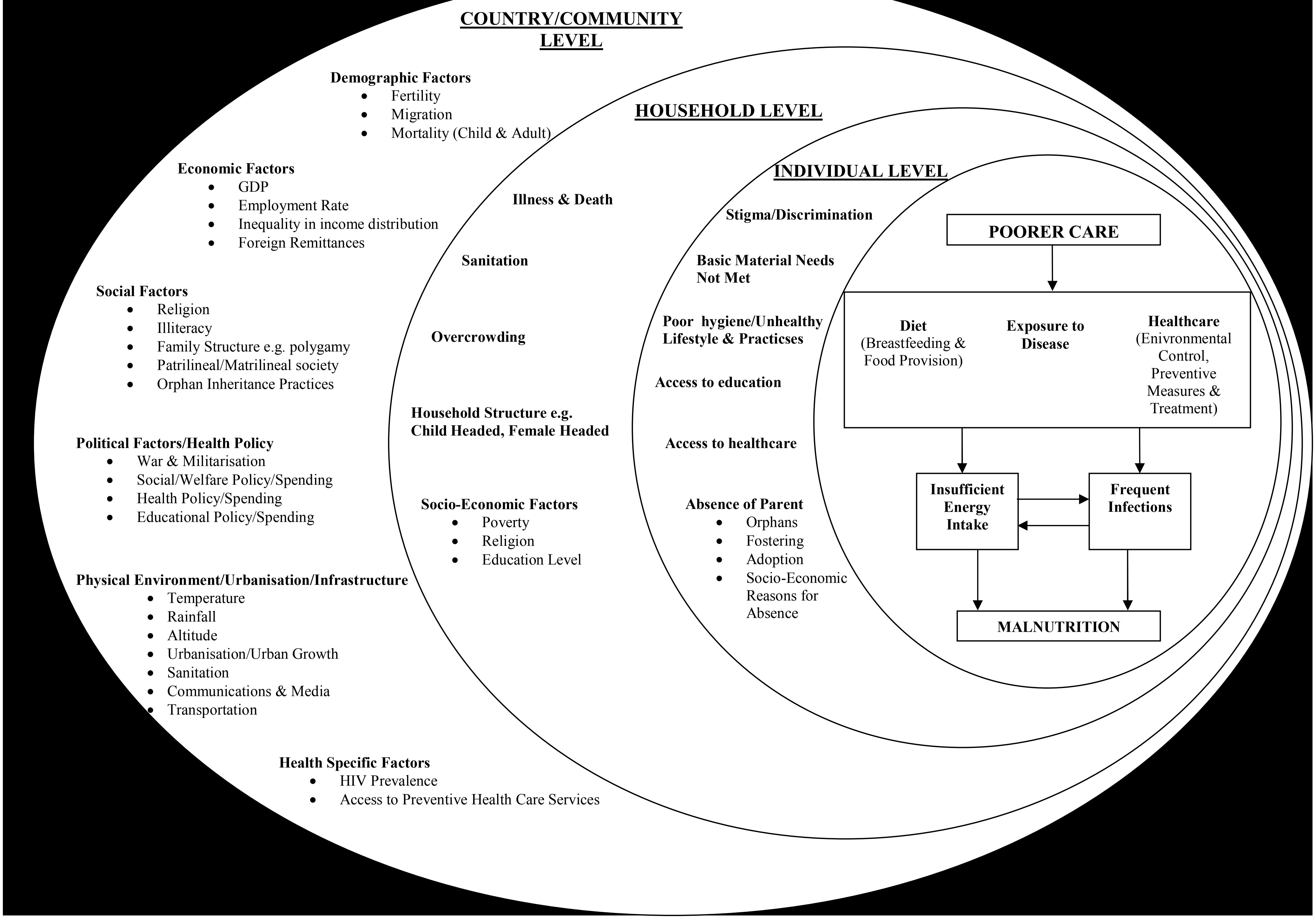
In some countries in sub-Saharan Africa orphanhood is associated with poor nutritional outcomes but in other countries it is not. Specific hypotheses regarding the interaction between orphan status and country HIV prevalence, GDP and household wealth index, with respect to nutritional outcomes, have been developed using a social epidemiological framework. These hypotheses have been investigated using Demographic and Health Survey data from several countries in sub-Saharan Africa. Multi-level modeling has been used to adjust for differences in variance at the sampling unit and country level. Results suggest there is no association between orphan status and poor nutritional outcomes in this dataset. There is also no evidence of an interaction between orphan status and country HIV prevalence, GDP or household wealth index. More general investigations into possible causal pathways between country-, household- and individual-level variables and nutritional status have also been conducted, with reference to the theoretical framework.

1 Introduction

A high prevalence of HIV across sub-Saharan Africa has led to an increase in adult mortality and consequently to a rise in the number of orphans. In 2003 there were 43 million orphans in the region, which represents an increase of over a third since 1990 (UNAIDS, 2004). Orphaned children (and those whose households are affected by AIDS related illnesses) may be disadvantaged compared to non-orphaned children with regards to access to healthcare, education and other social services. Mixed results have been found from investigations into the effects of orphanhood on child nutrition in sub-Saharan Africa. It would appear that results differ by country and region (Owen 2008; Rivers et al, 2008; Watts et al, 2007; UNICEF et al, 2003; Sarker et al, 2005; Crampin et al, 2003; Lindblade et al, 2003; Panpanich, 1999).

Extensive data has been collected from several countries in sub-Saharan Africa in national, cross-sectional, Demographic and Health Surveys (DHS). This data, and other country-specific data, can be used to investigate the effects of orphan status on nutritional outcomes and of the interaction between orphan status and various country, household and individual level variables, in particular household wealth status, GDP per capita and country-level HIV prevalence.

Figure 1: Theoretical Framework



1.1 Theoretical Framework

A complex series of risk factors influence child health and nutrition. A theoretical framework can aid the investigation of these risk factors and their causal pathways by clearly expressing assumptions about the causal structures involved and facilitating the formulation of explicit, testable hypotheses. Mosley & Chen (1984) proposed an analytical framework for the study of child survival in developing countries, which placed disease and malnutrition on the causal pathway between various risk factors and child mortality. They suggested that socio-economic factors would influence more proximate determinants of child health and nutrition, such as environmental contamination and dietary intake. They also suggested that there would be three levels of socio-economic determinants: individual level (e.g. orphan status; traditions, norms and attitudes), household level (e.g. income/wealth) and community level (ecological setting, political economy, health system). Owen (2008) developed the ideas of Mosley & Chen to produce a theoretical framework to investigate the causal pathways between the experiences of orphans and vulnerable children (OVC) and poor health and malnutrition. This framework and subsequent analyses focused primarily on individual factors and some household level factors. Community level factors were mentioned in the framework but were not made explicit and were not tested.

We have extended the framework to explicitly include country/community-level factors and a greater number of household level factors (figure 1). The structure of our framework has been heavily influenced by the framework of social epidemiology of HIV proposed by Poundstone et al (2004). They define social epidemiology as “the study of the distribution of health outcomes and their social determinants” and an ecosocial approach as one in which “factors at multiple levels – from the microscopic to the societal” contribute to the distribution of a disease. Although the emphasis of their paper was on population-level patterns of HIV/AIDS, we believe that the structure of their framework is relevant to the study of any disease or health related state with a complex series of risk factors operating at several different levels.

1.2 Hypotheses

There are a large number of causal pathways within our theoretical framework, which could be made explicit and then tested using available data. To identify and test all of these would be an unmanageably large task and would involve a redundantly large number of statistical tests. It is therefore necessary to identify specific hypotheses for investigation. In the context of the global HIV pandemic, which has increased the number of orphans in sub-Saharan Africa, and the mixed results that have been found regarding the effect of orphan status on child malnutrition, we have developed and tested the following hypotheses:

1. In countries with high HIV prevalence there will be higher incidence (and prevalence) of orphanhood. This will put pressure on the extended family network that traditionally copes with the care of orphans in sub Saharan Africa. This could lead to poorer care of orphans and thereby to higher levels of malnutrition amongst orphans in countries with high HIV prevalence compared to countries with low HIV prevalence. The effect of the high HIV prevalence will be mediated through household level variables such as overcrowding, lower socioeconomic status, elderly and child headed household heads and illness/death in the household.

2. Orphans living in the poorest households and the poorest countries will be more at risk of malnutrition than orphans living in richer households and/or countries as there will be fewer resources to facilitate the adequate care of orphans and other children. Thus there are likely to be higher levels of malnutrition amongst orphans living in poorer households and/or poorer countries compared to children living in richer households and/or countries. It is likely that several other household level effects - e.g. overcrowding, poor sanitation etc - will be on the causal pathway

that leads to orphans in poorer households/countries being at greater risk of malnutrition than orphans in richer households/countries.

As has been reported elsewhere (Robertson et al, 2008), there can be inaccuracies in the reporting of orphan status in demographic surveys. It is also possible that the absence of a biological parent may influence child health and nutrition regardless of whether that parent remains alive. We will therefore consider orphan status and fostering status (defined below) in the following analyses.

2 Data & Research Methods

Data were extracted from all completed DHS surveys conducted since 2003 in sub-Saharan Africa (see Table 1). The region of Africa assigned to each country is defined according to the United Nations Macro Regions & Components (2000). There are 19 countries represented in the dataset (Chad (2004) was excluded as nutritional data were not collected there). Nutritional data were collected from all (or in some cases a sub-set of) sampled children under 5 years in the surveys. Height-for-age (HAZ), weight-for-age (WAZ) and weight-for-height z-scores (WHZ) were calculated for each child using WHO Child Growth Standards (2006). Stunting (low HAZ) is generally used as an indicator of long-term and past levels of malnutrition in children, whereas wasting (low WHZ) measures more short-term changes in child nutrition. Underweight (low WAZ) is considered to be a composite of long-term and short-term effects (Kuate-Defo, 2001).

Our main analysis focuses on the role of selected household- and country/community-level indicators in mediating the effects of orphan status and fostering status on child nutrition. Individual data, including the orphan status, fostering status, sex and age of each child, are available from the DHS surveys.

The orphan status categories are defined as:

- Non-orphan – both parents are alive
- Maternal orphan – mother deceased; father alive
- Paternal orphan – father deceased; mother alive
- Double orphan – both parents deceased.

The fostering status categories are defined as:

- Child lives with both parents
- Child lives with father but not mother
- Child lives with mother but not father
- Child lives with neither parent.

Table 1: Demographic & Health Surveys - Country & Year

Country	Region of Africa*	Year
Benin	Western	2006
Burkino Faso	Western	2003
Cameroon	Middle	2004
Congo, Republic of	Middle	2005
Ethiopia	Eastern	2005
Ghana	Western	2003
Guinea	Western	2005
Kenya	Eastern	2003
Lesotho	Southern	2004
Madagascar	Eastern	2003/2004
Malawi	Eastern	2004
Mozambique	Eastern	2003
Niger	Western	2006
Nigeria	Western	2003
Rwanda	Eastern	2005
Senegal	Western	2005
Tanzania	Eastern	2004
Uganda	Eastern	2006
Zimbabwe	Eastern	2005/2006

*World Macro Regions and Components (UN 2000)

The DHS surveys also provide data on various household level indicators that were specified in the theoretical framework – type of toilet facility; age, sex and education level of the household head, number of people living in the house, urban/rural residence and wealth quintile. Each DHS country uses principal components analysis (PCA) to produce a household wealth index using country-specific data on household assets and utility services i.e. wealth indicator variables (Rutstein & Johnson, 2004). This index is then used to produce wealth quintiles for each country. PCA transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components (Last, 2001). The first principal component that is produced by the procedure is a synthetic variable that has a maximum correlation with all the original variables i.e. it provides the "best" summary of all the original variables. This procedure is applied to the DHS country-specific wealth indicator variables and the first principal component that is produced is used as the wealth index (Rutstein & Johnson, 2004). Wealth quintiles are then produced using this index. The cut points for the quintiles are calculated by obtaining a frequency distribution of households, weighted by the product of the number of de jure members of the household and the sampling weight[1] of the household. This distribution represents the national household population, with each member being given the wealth index score of his or her household. The individuals are then ordered by the score and the distribution is divided into quintiles. The household score is then recoded into the quintile variable so that all members of a household receive the household's quintile category. We make use of this categorical wealth index variable in our analyses.

Country level data, such as GDP per capita and HIV prevalence were available from various international and UN organisations (see table 2). We have tried to include variables that represent each of the major groups of country/community level factors – demographic factors, social factors, political factors, health policy, environment/urbanisation/infrastructure and other health specific factors. Not all sub-categories within these major groups are represented. This is because we wanted to focus on a select number of indicators of interest, particularly those relevant to social epidemiology (rather than, for example, environmental epidemiology). We also wanted to avoid conducting too many analyses or including too many highly correlated variables e.g. access to telephone lines and urbanisation. Finally, reliable data on some indicators were not available for several (or all) of the countries e.g. data on foreign remittances.

For some variables, country-level data were not collected and/or published every year. Where possible, data were extracted, for each country, from documents published in the same year as the DHS was carried out. If this was not possible, data from the nearest possible date were used. Rough estimates of the proportion of the population from each country identifying as Christian, Muslim or an indigenous religion were available from the CIA World Factbook 2003-2006. Most countries had only a small proportion of the population reporting an indigenous religion. The proportion identifying as Christian was strongly, negatively correlated with the proportion identifying as Muslim i.e. countries with a high proportion of people identifying as Christian would have a low proportion of people identifying as Muslim and vice versa. We therefore included only one of these variables (proportion of the population identifying as Christian) in the analyses.

Previous work has suggested that orphan inheritance patterns may influence the effects of different types of orphan status e.g. maternal, paternal or double on child wellbeing (Nyamukapa & Gregson, 2005). The country-level prevalence of different types of fostering (amongst orphans and non-orphans) was calculated from DHS data on fostering (see table 2). These indicators are intended to reflect varying societal structures and patterns of orphan inheritance.

When investigating whether country HIV prevalence is an effect modifier of the relationship between orphan status and malnutrition, countries were split into two groups – high prevalence countries and low prevalence countries. This split was made at the median (4%/5%) so that there were a roughly similar number of countries in each group. The same procedure was performed to split countries by their GDP per capita and the cut-off was at around US$4.75.

When the data from all 19 countries were combined the dataset became large and unmanageable, especially given the complexity of the statistical techniques being used. We therefore decided to restrict our analyses to children of a single age. Since, within the age-range 0-4 years, the largest number of orphans occurs amongst the four year olds, this age group was selected. These children will also have spent the longest time exposed to their orphan status, although there will be more variation in exposure time within this group than would be expected amongst younger children.

All analyses have been conducted in Stata 10.0 unless otherwise stated. Hierarchical (multi-level) statistical modelling is used to analyse nested data where different levels of variability are associated with each level of nesting (Rabe-Hesketh & Skrondal, 2005; Twisk 2006). There were four levels of hierarchy considered in this analysis – country, sample cluster, household and individual. In our hypotheses, we are interested in the interaction between individual and country level effects, so both of these levels were included in the models. The sample design for the DHS surveys is generally based on a stratified two-stage cluster design – enumeration areas (or sample clusters) are drawn from available census files and a sample of households within these clusters are selected from a list of households. Sample cluster was therefore also considered as a level in the hierarchical models.

95% of children in the analysis came from households with no other children aged 4 years. Thus household was not included as a level. However, to ensure that our results are not influenced by correlation, at the household level, among the 5% of children living in households that contributed more than one child to the analysis, the entire analysis was repeated on a subset of the data, in which only one child was selected at random from each household containing more than one eligible child.

Table 2: Country-Level Variables – Sources & Definitions

Country-Level Variable	Data Source	Range of Values
Average annual population growth rate (%)	State of the World Population 2003-2006	0.1% - 3.6%
Percent of national population living in urban areas	State of the World Population 2003-2006	13% - 54%
Health expenditure as a percent of total GDP	State of the World Population 2003-2006	0 - 8%
Military expenditure as a percent of total GDP*	Human Development Reports 2003-2006	0.6% - 4.3%
Percent of population with access to safe drinking water	State of the World Population 2003-2006	22% - 83%
Gross domestic product per capita ($US)	International Monetary Fund 2003-2006	1.32 - 57.56
Total Fertility Rate	State of the World Population 2003-2006	3 - 8
Percent of children aged 12-23 months received	World Bank 2003-2006	35% - 94%
HIV prevalence	UNAIDS 2003-2006	0.5% - 23.5%
Proportion of non-orphans living with neither parent	DHS 2003-2006	6.6% - 17.1%
Proportion of paternal orphans living with their mother	DHS 2003-2006	60.8% - 83.6%
Proportion of maternal orphans living with their father	DHS 2003-2006	28.0% - 72.1%
Adult Iliteracy rate (% of ages 15 and over)	Human Development Reports 2003-2006	10.0% - 75.2%
Inequality measure (GINI index**)	Human Development Reports 2003-2006	28.9 - 63.2
Percent of population christian	CIA World Factbook 2003-2006	5% - 94%
Percent of roads tarred	CIA World Factbook 2003-2006	4.2% - 47.4%

*Data on military expenditure not available from Benin, Guinea, Madagascar & Malawi
**A value of 0 represents perfect equality, and a value of 100 perfect inequality; data on GINI index not available from Republic of Congo

Hierarchical linear regression models were developed separately for each of the three nutritional outcome variables – WAZ, HAZ and WHZ. Random intercepts at the country and sample cluster level were added to the models and likelihood ratio tests were performed to assess the variation, across the countries and clusters, with respect to each of the nutritional outcomes. Sex adjusted multilevel models were then constructed to investigate the effect of orphan status on each nutritional outcome. Since the DHS surveys are not self-weighting (to ensure robust estimates of key demographic variables at urban/rural and province/regional level, when population sizes in these areas vary dramatically, some areas are oversampled) sample weights should be applied before conducting analyses of the data. Unfortunately, multilevel regression cannot be performed in Stata 10.0 whilst applying sample weights to the data. As a compromise, the variables “urban or rural residence” and “region”, which are the variables used in the sampling designs, are added as explanatory variables (as suggested in Madise et al, 1999) in all the analyses described below unless otherwise stated.

The interactions between orphan status and country HIV prevalence, GDP per capita and household wealth quintile were investigated using likelihood ratio tests to compare sex-adjusted models with and without interaction terms between orphan status and each of the effect modifiers. It is predicted from the initial hypotheses that the effect modification of orphan status by HIV prevalence and household/country wealth will be mediated through a number of household level factors, such as overcrowding and sanitation. To investigate this, household level variables were added to the models and the tests for interaction were repeated. Finally, we ran the models with orphan status included as a random coefficient (slope) and used likelihood ratio tests to compare these to models without a random slope for orphan status. This helped us to determine whether the effect of orphan status on nutritional outcomes differs by country. These models were computationally intensive and time consuming to run and therefore simpler versions of the models were used for these tests i.e. sample cluster was not included as a random intercept and sex, urban/rural residence and region were not included as covariates. Each of the above analyses were then repeated with fostering status as the main explanatory variable.

A more general exploratory analysis was also conducted. Sex-adjusted regression models, with urban/rural residence and region added as explanatory variables and with random intercepts at the country- and sample cluster-levels were created for each of the household-level variables. Those variables found to be associated with a nutritional outcome with a significance value of less than or equal to 0.2 (Mickey & Greenland, 1989) were then added as explanatory variables in a single adjusted model. To avoid an overload of statistical tests, the country-level variables were investigated graphically. Mean country-level nutritional z-scores for children aged 4 years were graphed against various country-level explanatory variables. Before calculating the country-level means, the data were set to take account of the sampling design including the application of sample weights where appropriate. This was done using the svyset command in Stata 10.0. All graphs and Pearson correlation coefficients were produced using Microsoft Excel 2003.

3 Results

There are 20216 children aged 4 years in the dataset. There are 20047 children with complete orphan data and 20186 children with complete fostering status data. Of those with complete orphan data there are 271 (1.35%) maternal orphans, 779 (3.89%) paternal orphans and 105 (0.52%) double orphans. Of those with complete fostering status data there are 606 (3.00%) children living with their father but not their mother, 3687 (18.27%) children living with their mother but not their father and 2175 (10.77%) children living with neither parent. The crude mean WAZ, across all countries is -1.17 (95% CI: -1.18-(-1.15)). The crude mean HAZ is -1.78 (95%CI: -1.80-(-1.76)) and the crude mean WHZ is -0.07 (95%CI: -0.08-(-0.05)).

For all three nutritional outcomes, the likelihood ratio test comparing models with country as a random intercept with models without country as a random intercept were highly significant ($p<0.0001$ for all three outcomes). Similar analyses investigating the inclusion of sample cluster as a random intercept, as well as country, were also highly significant for all three nutritional outcomes ($p<0.0001$ for all three outcomes). Table 3 shows the variance in the sample cluster- and country-level random intercepts, as well as the residual (or error) variance, by nutritional outcome variable, for each of three different models. For all three outcomes, the error variance decreases when a random intercept is added at the country-level and is further decreased when a random intercept at sample cluster level is added. These results suggest that there is significant variation in the mean nutritional z-scores across country and sample cluster. Moreover the model with random intercepts at both these levels provides a better fit to the nutritional data than the naïve model. The variance in the sample cluster level intercepts is greater than the variance in the country level intercepts for all three outcomes. However, the addition of a random intercept at sample cluster level does not affect the size of the variance in the country level intercepts. This indicates that there is greater variation in nutritional z-scores across sample cluster than across country and that the variation at the sample cluster level is independent of the variation at the country level. Similar results were found when these analyses were repeated on a subset of the data where one child, at random, was sampled from each house containing more than one child aged four years.

Table 3 Variance in the sample cluster- and country-level random intercepts & the error variance, by nutritional outcome variable, for three different hierarchical models

	Weight-for-Age Z-Score			Height-for-Age Z-Score			Weight-for-Height Z-Score		
	Residual Variance (S.E.)	Variance of Country Level Intercepts (S.E.)	Variance of Sample Cluster Level Intercepts (S.E.)	Residual Variance (S.E.)	Variance of Country Level Intercepts (S.E.)	Variance of Sample Cluster Level Intercepts (S.E.)	Residual Variance (S.E.)	Variance of Country Level Intercepts (S.E.)	Variance of Sample Cluster Level Intercepts (S.E.)
Naïve Model (i.e. no random intercept)	1.319 (0.013)	-	-	2.203 (0.022)	-	-	1.618 (0.016)	-	-
Country Level Random Intercept Model	1.260 (0.013)	0.068 (0.023)	-	2.129 (0.021)	0.085 (0.029)	-	1.531 (0.015)	0.093 (0.031)	-
Country & Sample Cluster Level Random Intercept M	1.104 (0.013)	0.067 (0.022)	0.157 (0.010)	1.842 (0.022)	0.087 (0.029)	0.290 (0.018)	1.333 (0.016)	0.090 (0.030)	0.197 (0.012)

3.1 Orphan Status & Nutritional Z-Scores

In sex-adjusted, hierarchical models, with a random intercept for country and sample cluster, there is no evidence that maternal orphans or paternal orphans have lower nutritional z-scores (see table 4). There is limited evidence that double orphans have lower WAZ (mean difference=-0.21; p=0.089). There is no evidence of an interaction between orphan status and country HIV prevalence, household wealth index or country GDP per capita (table 4). The models with orphan status included as a random slope did not explain the variation in the data better than models where orphan status was not included as a random slope i.e. the likelihood ratio tests were not significant (see table 4). This suggests that the effects of orphan status do no differ significantly by country. The results of these analyses remained similar when they were repeated on a subset of the data where only one child was selected at random from each household containing more than one child aged 4 years.

3.2 Fostering Status & Nutritional Z-Scores

In sex-adjusted, hierarchical models, with a random intercept for country and sample cluster, there is no evidence that children who do not live with either (or both) of their parents have lower nutritional z-scores (table 5). There is no evidence of an interaction between fostering status and household wealth index or country GDP per capita in any of the models (table 5).

There is weak evidence of an interaction between fostering status and country HIV prevalence with respect to their effects on HAZ (p=0.065). There is stronger evidence of an interaction between fostering status and country HIV prevalence with respect to WHZ (p=0.0003). The interaction between fostering status and country HIV prevalence remains significant in the WHZ model after adjusting for household level variables (p=0.0002). The significance of the interaction is reduced, following adjustments, in the HAZ model (p=0.085).

To further investigate these interactions, figure 2 shows the effects of each category of fostering status on HAZ and WHZ, compared to living with both parents, by country HIV prevalence. Unfortunately, the pattern of the effect of fostering status on malnutrition, across high and low HIV prevalence countries, is not particularly clear. In low HIV prevalence countries, the mean difference in WHZ between children living with their mother but not their father and children living with both parents tends to be greater (and more negative) compared to the mean difference in countries with higher HIV prevalence. A similar pattern is seen for the mean difference in WHZ between children living with neither parent and children living with both their parents. It should be noted that there are only four countries with HIV prevalence greater than 10%.

The models with fostering status included as a random slope showed mixed results when compared to models where fostering status was not included as a random slope (see table 5). The mean difference in z-scores between children living with their father but not their mother and children living with both their parents did not vary significantly by country regardless of the measure of malnutrition being considered. However, the mean differences in z-score between children living with their mother and not their father and children living with both their parents shows significant variation across the countries. The effect of living with neither parent compared to both parents does not differ across countries except with respect to WHZ.

The results of the above analyses remained similar when they were repeated on a subset of the data where only one child was selected at random from each household containing more than one child aged 4 years.

3.3 General Exploratory Analysis – Weight-for-Age Z-Score (WAZ)

The sex-adjusted models with different household level explanatory variables and with country and sample cluster as random intercepts indicate that children living in the poorest households, in households without flushing toilets or pit-latrines, with less educated household heads and in rural areas are more likely to have low WAZ (table 6). In the fully-adjusted household level model, wealth status, education level of the household head, and urban residence remain significantly associated with increased WAZ, although the effect sizes are reduced. The effect of type of toilet on WAZ is reduced in the fully adjusted model and is no longer statistically significant. These results remained similar when the analyses were repeated on a subset of the data where only one child was selected at random from each household containing more than one child aged 4 years.

Figure 3 show the distribution of mean WAZ by various country-level variables. From these graphs and the Pearson correlation coefficients (“corr”) it can be seen that country-level mean WAZ tends to increase with increasing GDP per capita (corr=0.52), percentage of the population living in urban areas (corr=0.56), percentage of the population with access to safe drinking water (corr=0.50) and decreasing illiteracy rate (corr=-0.51). Among countries with an HIV prevalence of less than 10%, there appears to be an increase in mean WAZ as HIV prevalence increases. However, amongst the few countries with HIV prevalence greater than 10%, this trend seems to disappear and overall the correlation coefficient is quite low (corr=0.28). GDP per capita is highly, positively correlated with the percentage of the population living in urban areas (corr=0.69), although it is only weakly correlated with access to clean drinking water (corr=0.05), illiteracy rate (corr=-0.30) and HIV prevalence (corr=-0.02).

Table 4: Sex-Adjusted Effects of Orphan Status on Nutritional Z-Scores (Multilevel Model

	Weight-for-Age Z-Score				Height-for-Age Z-Score				Weight-for-Height Z-Score			
	Mean Difference	95% CI	p-value	Test of Random Slope* (p-value)	Mean Difference	95% CI	p-value	Test of Random Slope* (p-value)	Mean Difference	95% CI	p-value	Test of Random Slope* (p-value)
Maternal Orphan vs Non-Orphan	-0.053	-0.185-0.080	0.436	0.356	0.035	-0.137-0.207	0.689	0.370	-0.079	-0.226-0.068	0.291	0.229
Paternal Orphan vs Non-Orphan	0.012	-0.067-0.091	0.771	0.606	-0.052	-0.156-0.051	0.320	MA**	-0.008	-0.097-0.080	0.856	0.244
Double Orphan vs Non-Orphan	-0.144	-0.355-0.067	0.181	0.338	-0.047	-0.322-0.227	0.736	0.939	-0.205	-0.441-0.031	0.089	0.235
Test for Interaction with Country HIV Prevalence	-	-	0.892		-	-	0.839		-	-	0.302	
Test for Interaction with Household Wealth Index	-	-	0.863		-	-	0.776		-	-	0.377	
Test for Interaction with GDP per Capita	-	-	0.548		-	-	0.488		-	-	0.717	

*Test of random slope for orphan status at the country level

**Maximisation aborted

Table 5: Sex-Adjusted Effects of Fostering Status on Nutritional Z-Scores (Multilevel Model)

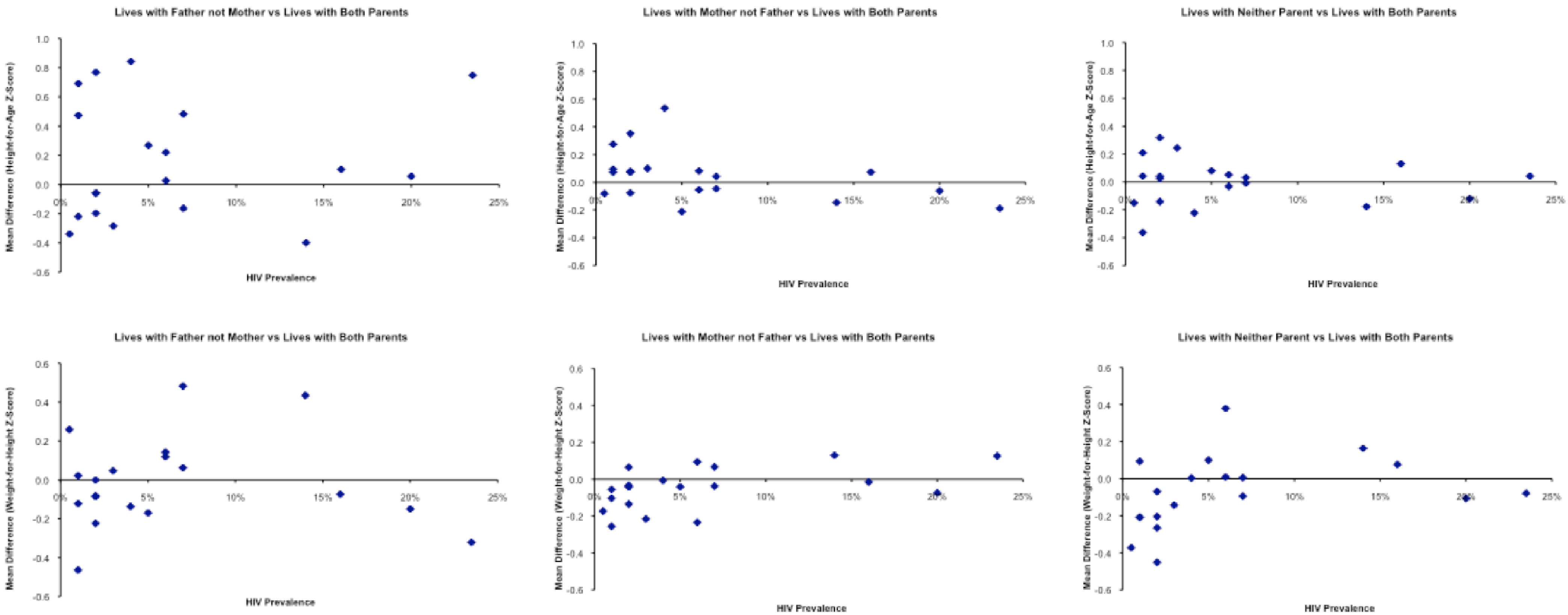
	Weight-for-Age Z-Score				Height-for-Age Z-Score				Weight-for-Height Z-Score			
	Mean Difference	95% CI	p-value	Test of Random Slope*** (p-value)	Mean Difference	95% CI	p-value	Test of Random Slope*** (p-value)	Mean Difference	95% CI	p-value	Test of Random Slope*** (p-value)
Lives with Father not Mother vs Lives with Both Parents*	0.049	-0.041-0.138	0.289	0.172	0.080	-0.037-0.198	0.181	0.838	0.011	-0.089-0.111	0.832	0.827
Lives with Mother not Father vs Both Parents*	-0.005	-0.046-0.036	0.810	0.057	-0.012	-0.066-0.041	0.647	0.007	-0.022	-0.067-0.024	0.352	0.097
Lives with Neither Parent vs Both Parents*	0.0002	-0.050-0.051	0.995	0.105	0.007	-0.059-0.073	0.827	0.742	-0.005	-0.062-0.051	0.857	0.003
Interaction with Country HIV Prevalence*	-	-	0.175		-	-	0.063		-	-	0.0003	
Interaction with Household Wealth Index*	-	-	0.495		-	-	0.704		-	-	0.272	
Interaction with GDP*	-	-	0.369		-	-	0.954		-	-	0.178	
Adjusted Interaction with Country HIV Prevalence**	-	-	-		-	-	0.085		-	-	0.0002	
Adjusted Interaction with Household Wealth Index**	-	-	-		-	-	-		-	-	-	
Adjusted Interaction with GDP**	-	-	-		-	-	-		-	-	-	

*sex adjusted

**adjusted for wealth index quintile; type of toilet facility; number of people in the household; age, sex and education level of the household head, urban/rural region

***Test of random slope for foster status at the country level; not sex adjusted

Figure 2: Effects of Fostering Status on Height-for-Age and Weight-for-Height Z-Scores by Country HIV Prevalence



The percentage of non-orphaned children living with neither of their natural parents and the percentage of maternal orphans living with their father varies across the countries (7% to 17% and 28% to 72% respectively). As the proportion of maternal orphans living with their father increases, the mean country-level WAZ decreases (corr=-0.57). As the percentage of non-orphaned children living with neither parent increases, the mean WAZ appears to increase too, although the correlation is not particularly strong (corr=0.44). As might be expected, in countries where fostering seems to be popular i.e. where a high percentage of non-orphans live with neither parent, there also tends to be a low proportion of maternal orphans living with their father (corr=-0.64). The proportion of paternal orphans living with their mother is consistently higher than the percentage of maternal orphans living with their father and ranges from 61% to 84% across the various countries. There does not appear to be a trend in mean WAZ as the percentage of paternal orphans living with their mother changes (corr=-0.29).

3.4 General Exploratory Analysis – Height-for-Age Z-Score (HAZ)

The sex-adjusted models with different household level explanatory variables and with country and sample cluster as random intercepts indicate that children living in the poorest households, in households without flushing toilets or pit-latrines, with less educated household heads and in rural areas are more likely to have low HAZ (table 7). In the fully-adjusted, household level model, the effect sizes for wealth status, education level of the household head and living in a rural area are reduced but remain statistically significant. Having a flushing toilet or pit-latrine is no longer protective against low HAZ in the fully-adjusted model. These results remained similar when the analyses were repeated on a subset of the data where only one child was selected at random from each household containing more than one child aged 4 years.

Figure 4 shows the distribution of mean HAZ by various country-level variables. These graphs suggest that country-level mean HAZ increases as GDP per capita (corr=0.61) and percentage of the population living in urban areas (corr=0.76) increases. Unlike WAZ, the prevalence of fostering does not correlate particularly strongly with HAZ.

3.5 General Exploratory Analysis – Weight-for-Height Z-Score (WHZ)

The sex-adjusted models with different household level explanatory variables and with country and sample cluster as random intercepts indicate that children living in the poorest households, in households without flushing toilets or pit-latrines and with less educated household heads are more likely to have low WHZ, although these associations are weaker than in the WAZ and HAZ models (table 8). In the sex-adjusted model, rural residence is not associated with a lower z-score – unlike the previous WAZ and HAZ models. In the fully-adjusted household model, those living in households without a flushing toilet still have higher WHZ. However, wealth status and education level of the household head are not significantly associated with WHZ in the fully-adjusted model. The effect size for living in a rural versus an urban area increases in the fully-adjusted model, with children living in rural areas having significantly higher WHZ. Again, this differs from the results of the WAZ and HAZ models, where children in rural areas had significantly lower z-scores. All of these results remained similar when the analyses were repeated on a subset of the data where only one child was selected at random from each household containing more than one child aged 4 years.

Figure 5 shows the distribution of mean WHZ by various country-level variables. These graphs suggest that mean WHZ increase as the percentage of the population identifying as Christian increases (corr=0.53) and the percentage of maternal orphans living with their father decreases (corr=-0.63). However, there does not appear to be a strong correlation between WHZ and percentage of non-orphans living with neither of their parents (corr=0.27) or the percentage of paternal orphans living with their mother (corr=-0.26). There is evidence that mean WHZ increases with increasing HIV prevalence (corr=0.47), although, as with WAZ, this trend is more apparent amongst countries with prevalence less than 10%.

4 Discussion

We have developed a theoretical framework that illustrates the relationship between various underlying factors at the country/community-, household- and individual-level and child malnutrition. These underlying factors influence patterns of child malnutrition through more proximate factors such as environmental contamination and poor diet. This framework was used to develop hypotheses regarding the country- and household-level factors that modify the effects of orphan status and fostering status on child malnutrition. These hypotheses were then tested using hierarchical statistical models applied to data from 19 countries of sub-Saharan Africa.

There was strong evidence that the level of malnutrition varied significantly across countries and regions within countries. However, there was no evidence, in this data, that being an orphan significantly increased the risk of malnutrition amongst children aged 4 years. These findings are consistent with evidence from some previous studies focusing on data from single countries (Sarker et al, 2005; Crampin et al, 2003; Panpanich, 1999) and data from several countries (Rivers et al, 2008), which found no association between orphan status and malnutrition. However, other studies from single countries found that there was an association (Miller et al, 2007; Watts et al, 2007; Lindblade et al, 2003).

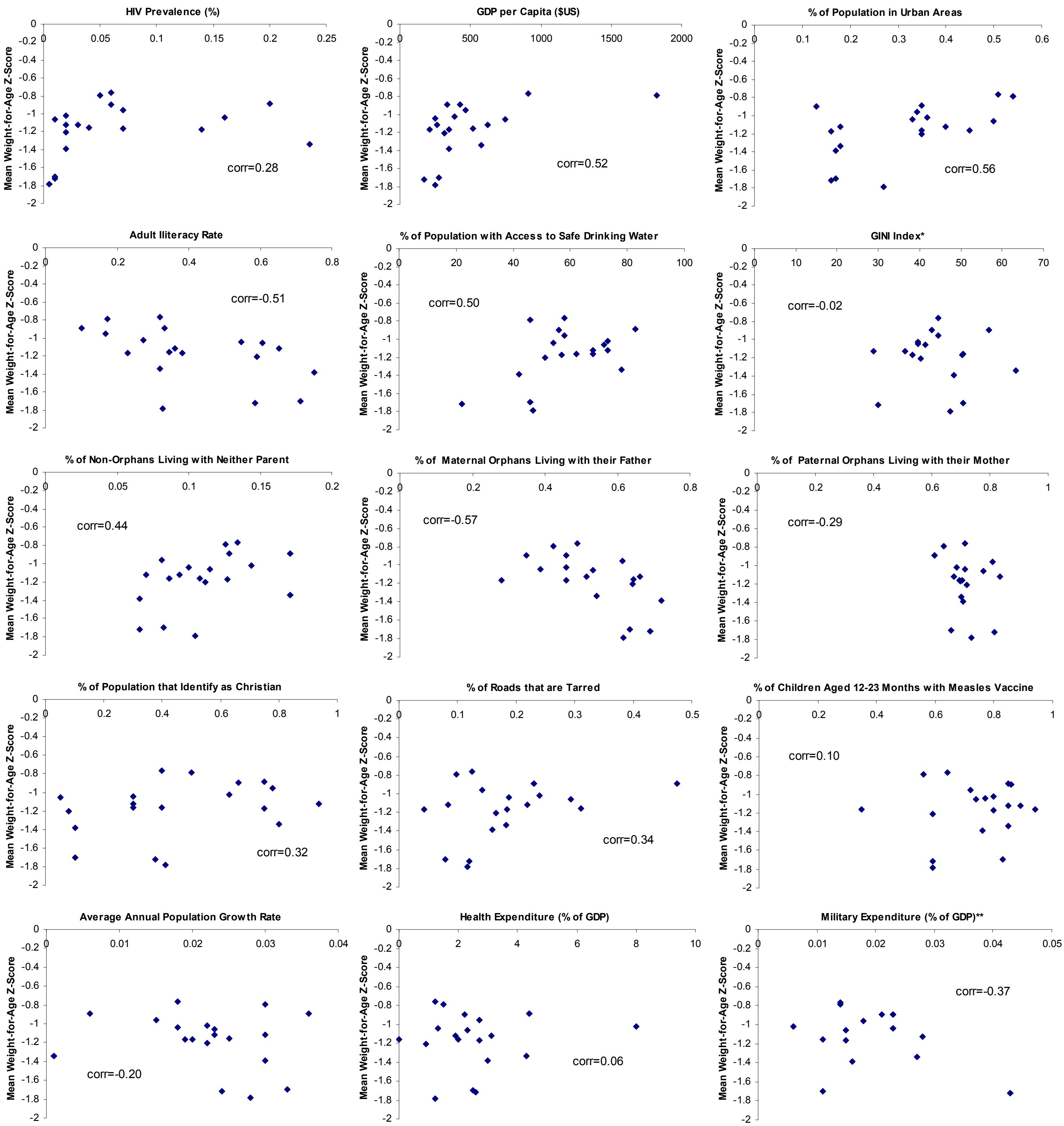
Table 6: Effects of Household Level Variables on Weight-for-Age Z-Score (Multilevel Model)

	Sex Adjusted*			Fully Adjusted**		
	Mean Difference	95% CI	p-value	Mean Difference	95% CI	p-value
Poorer vs Poorest Household	0.058	0.011-0.105	0.016	0.045	-0.003-0.093	0.067
Middle vs Poorest Household	0.150	0.103-0.198	<0.0001	0.129	0.078-0.179	<0.0001
Richer vs Poorest Household	0.252	0.201-0.303	<0.0001	0.214	0.158-0.270	<0.0001
Richest vs Poorest Household	0.522	0.462-0.583	<0.0001	0.434	0.364-0.503	<0.0001
Flush/Pit Latrine Toilet vs None/Other in Household	0.156	0.116-0.196	<0.0001	0.004	-0.040-0.049	0.850
More than Six People in House vs Less than Six	-0.020	-0.052-0.012	0.214	-0.018	-0.050-0.013	0.256
Household Head has Primary Education vs None	0.114	0.074-0.153	<0.0001	0.075	0.035-0.115	<0.0001
Household Head has Secondary Education vs None	0.291	0.240-0.342	<0.0001	0.186	0.133-0.239	<0.0001
Household Head has Higher Education vs None	0.538	0.441-0.634	<0.0001	0.364	0.265-0.464	<0.0001
Household Head is Female vs Male	0.004	-0.036-0.045	0.828	-	-	-
Elderly Household Head vs Non-Elderly	0.016	-0.031-0.064	0.499	-	-	-
Rural vs Urban Residence	-0.357	-0.398-(-0.317)	<0.0001	-0.091	-0.140-(-0.042)	<0.0001

*adjusted for sex of respondent, urban/rural residence and DHS region

**adjusted for sex of respondent, DHS region, urban/rural residence, household wealth index quintile, type of toilet in house, number of people in house and education level of the household head

Figure 3: Distribution of Mean Weight-for-Age Z-Score by Various Country Level Variables



*no data on GINI index available for Republic of Congo
**no data on military expenditure available for Benin, Guinea, Madagascar or Malawi

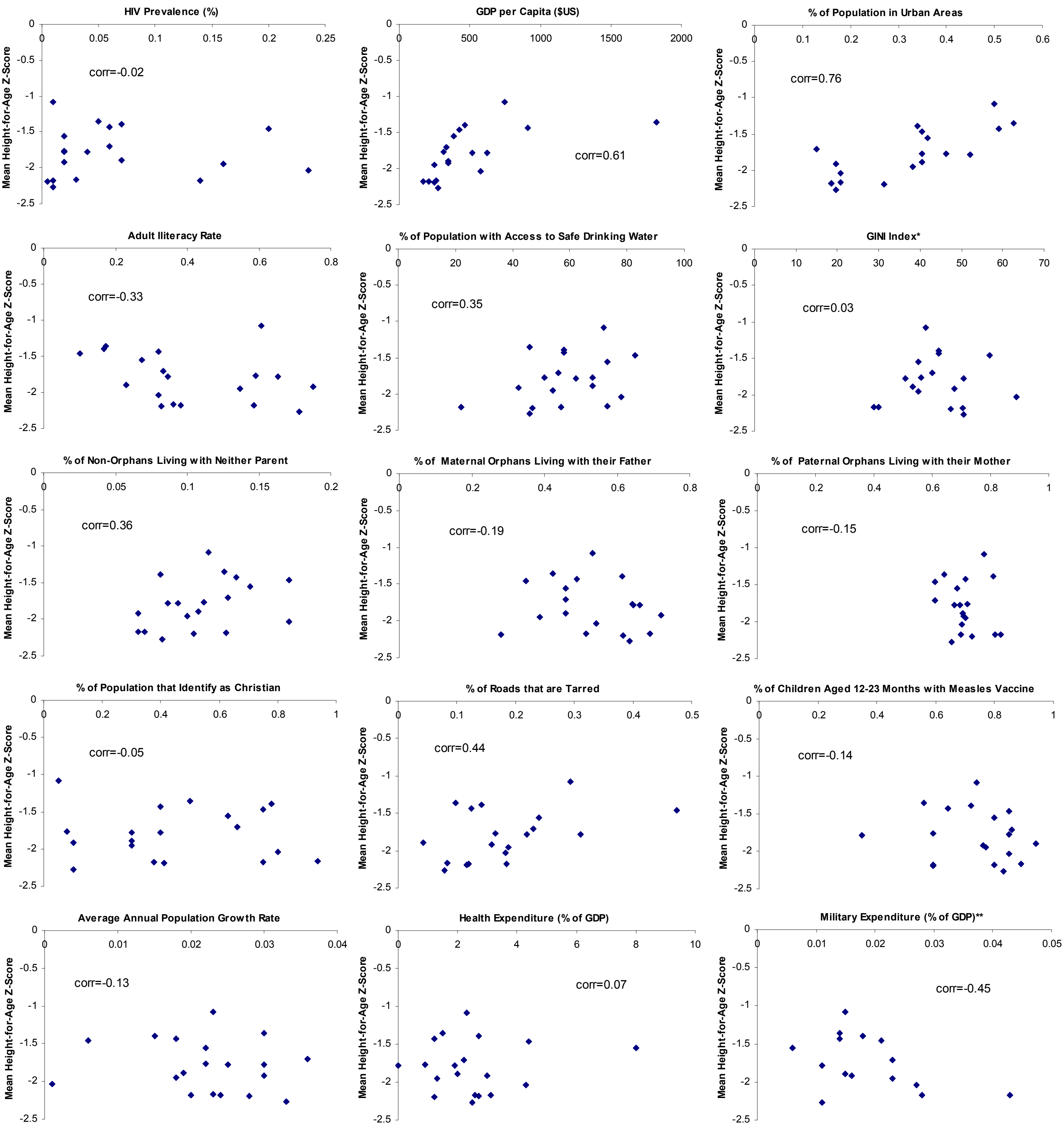
Table 7: Effects of Household Level Variables on Height-for-Age Z-Score (Multilevel Model)

	Sex Adjusted*			Fully Adjusted**		
	Mean Difference	95% CI	p-value	Mean Difference	95% CI	p-value
Poorer vs Poorest Household	0.050	-0.011-0.111	0.111	0.042	-0.020-0.105	0.182
Middle vs Poorest Household	0.122	0.060-0.184	<0.0001	0.113	0.047-0.178	0.001
Richer vs Poorest Household	0.308	0.242-0.375	<0.0001	0.289	0.216-0.361	<0.0001
Richest vs Poorest Household	0.701	0.622-0.780	<0.0001	0.630	0.541-0.720	<0.0001
Flush/Pit Latrine Toilet vs None/Other in Household	0.158	0.105-0.210	<0.0001	-0.051	-0.109-0.007	0.088
Household Head has Primary Education vs None	0.120	0.068-0.172	<0.0001	0.076	0.024-0.128	0.004
Household Head has Secondary Education vs None	0.365	0.299-0.431	<0.0001	0.230	0.162-0.298	<0.0001
Household Head has Higher Education vs None	0.652	0.527-0.777	<0.0001	0.415	0.287-0.543	<0.0001
More than Six People in House vs Less than Six	-0.015	-0.056-0.026	0.476	-	-	-
Household Head is Female vs Male	0.026	-0.026-0.078	0.329	-	-	-
Elderly Household Head vs Non-Elderly	0.003	-0.058-0.065	0.915	-	-	-
Rural vs Urban Residence	-0.599	-0.652-(-0.547)	<0.0001	-0.240	-0.304-(-0.177)	<0.0001

*adjusted for sex of respondent, urban/rural residence and DHS region

**adjusted for sex of respondent, DHS region, urban/rural residence, household wealth index quintile, type of toilet in house and education level of the household head

Figure 4: Distribution of Mean Height-for-Age Z-Scores by Various Country Level Variables



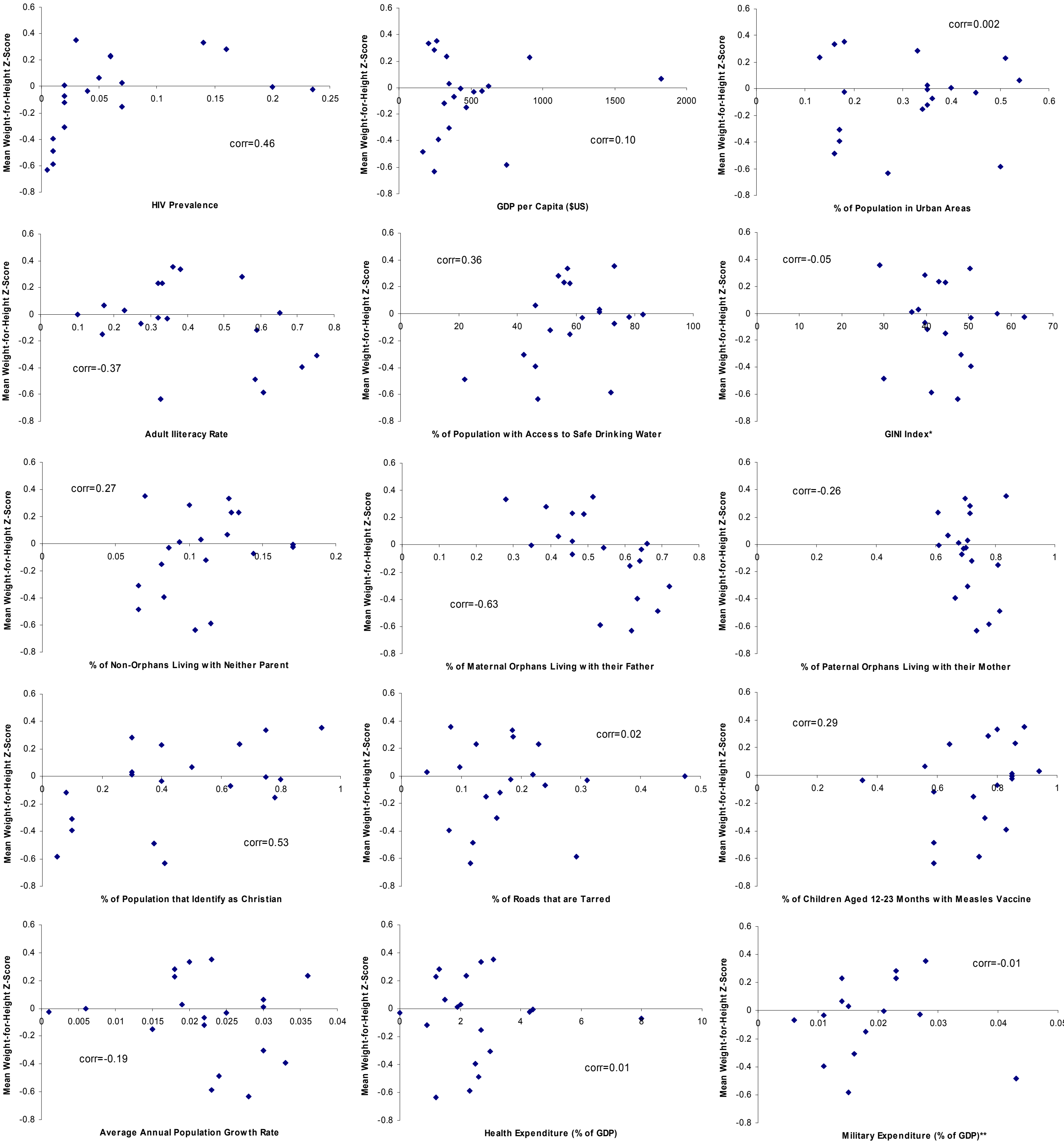
*no data on GINI index available for Republic of Congo
**no data on military expenditure available for Benin, Guinea, Madagascar or Malawi

Table 8: Effects of Household Level Variables on Weight-for-Height Z-Score (Multilevel Model)

	Sex Adjusted*			Fully Adjusted**		
	Mean Difference	95% CI	p-value	Mean Difference	95% CI	p-value
Poorer vs Poorest Household	0.018	-0.035-0.071	0.496	0.005	-0.050-0.059	0.869
Middle vs Poorest Household	0.079	0.025-0.132	0.004	0.052	-0.004-0.109	0.071
Richer vs Poorest Household	0.062	0.004-0.120	0.037	0.026	-0.037-0.089	0.420
Richest vs Poorest Household	0.109	0.040-0.178	0.002	0.043	-0.035-0.121	0.282
Flush/Pit Latrine Toilet vs None/Other in Household	0.083	0.038-0.128	<0.0001	0.059	0.009-0.110	0.022
More than Six People in House vs Less than Six	-0.028	-0.064-0.008	0.123	-0.027	-0.063-0.009	0.138
Household Head has Primary Education vs None	0.038	-0.006-0.083	0.092	0.025	-0.020-0.070	0.278
Household Head has Secondary Education vs None	0.064	0.006-0.121	0.029	0.038	-0.021-0.098	0.207
Household Head has Higher Education vs None	0.182	0.072-0.291	0.001	0.146	0.033-0.258	0.012
Household Head is Female vs Male	-0.007	-0.052-0.037	0.745	-	-	-
Elderly Household Head vs Non-Elderly	0.009	-0.043-0.062	0.725	-	-	-
Rural vs Urban Region	0.032	-0.014-0.078	0.174	0.086	0.030-0.142	0.003

*adjusted for sex of respondent, urban/rural residence and DHS region
**adjusted for sex of respondent, DHS region, urban/rural residence, household wealth index quintile, type of toilet in house, number of people in house and education level of the household head

Figure 5: Distribution of Mean Weight-for-Height Z-Scores by Various Country Level Variables



*no data on GINI index available for Republic of Congo
**no data on military expenditure available for Benin, Guinea, Madagascar or Malawi

Following stratification by country HIV prevalence, GDP per capita and household wealth index, there remained no evidence of an association between orphan status and malnutrition. It should also be noted there was no evidence that the effect of orphan status on malnutrition varied across countries. These results are consistent with the null hypotheses i.e. that there is no interaction between measures of child malnutrition and HIV prevalence, GDP per capita or household wealth index in this dataset. A strong, negative correlation between GDP per capita and country HIV prevalence could mask the effects of these variables on the relationship between orphan status and malnutrition. However, a strong correlation was not observed between these variables in our data.

In simple, sex-adjusted analyses, children not living with their parents did not appear to be at increased risk of poor nutrition. However, there was evidence that the effect on children, with respect to malnutrition, of living with their mother but not their father (and for WHZ the effect of living with neither parent), compared to living with both parents varies across the countries. When the data are stratified, a significant interaction is found between fostering status and country HIV prevalence with respect to WHZ. This interaction remains significant after adjusting for various household level variables. The graphs suggest that in countries with high HIV prevalence there are only small differences between children living with their mother but not their father (or children living with neither parent) and children living with both their parents with respect to mean WHZ. In low HIV prevalence countries this difference is larger i.e. the fostered children tend to have lower WHZ. This is the opposite of what was predicted in the initial hypotheses.

It may be the case that the most vulnerable children in countries with high HIV prevalence are not captured by the cross-sectional DHS surveys due to higher mortality resulting from vertical transmission and the negative impact of parents, guardians and other community members with AIDS. If children who are more likely to live away from their parents are also more likely to suffer increased mortality, this could result in a selection bias as HIV prevalence increases, with only the healthier fostered children surviving. This could explain the lack of difference in z-scores between fostered and non-fostered children in high HIV prevalence countries compared to low HIV prevalence countries. If orphans are particularly vulnerable they may also suffer excess mortality compared to non-orphans and would therefore be missed by the cross-sectional study thus explaining the lack of association with malnutrition. However, if this were the case, we might expect an interaction with HIV prevalence as seen for fostering status. It should be remembered that there are only four very high prevalence (greater than 10%) countries included in the analysis, so it is difficult to draw strong conclusions. There may also be other country-level indicators that account for some of the variability in the effects of fostering status between countries and may be confounding the relationship with HIV prevalence.

This analysis has a number of strengths. The dataset is large and consists of nationally representative data. The use of anthropometric outcomes prevents reporting bias from influencing the outcome variables, although there may be some problems with reporting of orphan status, in particular maternal orphans are often underestimated in demographic surveys (Robertson et al, 2008). Underestimation of maternal orphanhood within the dataset could mask potential adverse effects of orphanhood on child nutrition. The cross-sectional nature of the data is a limitation. In particular, it is not clear whether parental death/absence occurred before or after the malnutrition manifested itself. This could mask the effects of orphan/fostering status on malnutrition and limits the scope for making inferences regarding causal mechanisms.

Our theoretical framework suggests several household level factors that may influence child malnutrition. Our analyses indicate that children living in poor, less educated and rural households are more likely to be malnourished. These results generally remained significant following adjustment for other household level factors and are consistent with several previous studies (Tumwire & Burugahare, 2002; Zere & McIntyre, 2003; Mamabolo et al, 2005; Smith et al, 2005; Steyn et al, 2005; Odunayo & Oyewole, 2006; Hong, 2007), in particular the independent effects of socio-economic status after controlling for urban/rural residence (Kennedy et al, 2006; Fotso, 2007). These factors influence child malnutrition by influencing more proximate determinants of child malnutrition i.e. by reducing the quality and quantity of food provision, increasing exposure and vulnerability to childhood illnesses and preventing access to health services and health education.

Our theoretical framework also specifies the influence of country/community-level factors on child malnutrition. We investigated some of these using scatter plots and Pearson correlation coefficients. WAZ is influenced by long-term and short-term changes in child nutrition. The largest number of country-level variables is associated with it – higher GDP per capita, high urbanization and low adult illiteracy are all associated with increased mean WAZ. This is likely to be due to increased food security, improved sanitation and greater access to health/education services as a result of economic development and improved infrastructure in richer countries with a greater proportion of the population living in urban areas. Lower adult illiteracy may also signify a population that is better able to prevent malnutrition through greater awareness of its causes and the various preventative measures.

Countries with a high percent of maternal orphans living with their father are more likely to have a low mean WAZ. It was hoped that the country-level fostering variables would crudely represent societal structures and patterns of orphan inheritance. If children are inherited down the paternal line, maternal orphans will be cared for by their fathers and possibly their fathers' new partners. There is evidence that this can result in poor standards of care (Nyamukapa & Gregson, 2005). However, we must be careful to avoid the ecological fallacy – it is not clear that poor nutrition amongst orphans is the principle determinant of this pattern and a patriarchal inheritance structure may have more general consequences for all children. It is also useful to note that the percentage of non-orphans living with neither parent showed a strong, negative correlation with the proportion of maternal orphans living with their father, as might be expected. Thus the association may indicate that malnutrition is lower in countries where fostering is common and generally acceptable. This may be because fostering facilitates the sharing of child caring responsibilities across the extended family network, which may be an optimal strategy when resources are limited.

HAZ reflects the long term, cumulative effects of malnutrition. Countries with high GDP per capita and high levels of urbanization tended to have higher mean HAZ. It is likely that the positive effects of economic development and urbanisation are also cumulative and influence nutrition throughout the life of a child, which may explain why these associations are found with mean WAZ and mean HAZ but not with mean WHZ, which reflect more recent changes in child nutrition.

Countries with high HIV prevalence, high proportion of the population identifying as Christian and low proportion of maternal orphans living with their father tend to have higher mean WHZ. It is not clear why increased HIV prevalence should be associated with higher mean WHZ. Perhaps malnourished children are being removed from this cross-sectional sample due to increased mortality among these children in high HIV prevalence countries. It is also unclear how the proportion of the population identifying as Christian affects nutrition – the association may be due to several political and/or socio-cultural/behavioural factors. However, it should also be noted that accurate information on the prevalence of each religion was not available and the CIA World Factbook provided only approximate estimates. Additionally, it is important to remember the ecological fallacy – it may not be the members of the predominant religion within a country that experience the increased risk of child malnutrition in that country.

Aside from the ecological fallacy, the analyses of country-level risk factors for malnutrition were limited by the fact that for some national level variables the data used were not collected in the same year as the DHS due to lack of availability. For instance, data on GDP per capita and HIV prevalence are produced annually but data on adult illiteracy are collected much less frequently. This may have confused some of the relationships presented here. Finally, we did not investigate all factors at the household- or country/community-level that were listed in our theoretical framework e.g. country-level migration patterns or the effects of foreign remittances. Thus we may have failed to demonstrate some important relationships because we did not investigate them.

We used a theoretical framework to develop hypotheses about the relationship between orphan/fostering status and various household and country-level variables. We found no evidence that orphan status or fostering status has an effect on child nutrition and we found very little evidence to support our hypotheses that country HIV prevalence or household or country-level wealth indicators modify the effect of orphan status and/or fostering status. Despite this, the framework remains a useful tool for generating new hypotheses regarding the effects of different social factors on child health and nutrition. Further exploration of this framework would benefit from the use of cohort data, which could provide insights into the effects of various risk factors, including orphan status, and their interactions over time. Such data would provide more robust evidence for temporal associations and would allow stronger inferences about causal pathways to be drawn.

Endnotes

1. DHS surveys are not self-weighting. In order to ensure robust estimates of key demographic variables at urban/rural and province/regional level, when population sizes in these areas vary dramatically, some areas are oversampled in DHS surveys. Thus the surveys are not self-weighting and sample weights should be applied to the data when conducting analyses.

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