Economic and Gender Inequalities are Important Determinants of Anaemia and Acute Malnutrition in Children aged <5 years in Low- and Middle-Income Countries

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Keywords

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Abstract

Background: Poverty is a known determinant of malnutrition, especially in less-affluent countries. However the large variance in malnutrition, prevalence noted across these countries cannot be fully explained by differences in national wealth alone. Therefore, additional socioeconomic factors e.g. inequalities, are likely to also contribute towards this variance. This study aimed to explore the possible associations between economic and gender inequalities with malnutrition in children aged <5years, specifically anaemia and global acute malnutrition (GAM), using data from Low and Middle-Income Countries.
Methods: Anaemia and GAM prevalence data was obtained for 48 countries from the DHS STATcompiler and for 7 countries for which this data was countries unavailable, it was obtained from the World Bank, WHO and UNICEF data. The World Bank's Gini Index and UNDP's Gender Inequality Index (GII) were used to measure economic inequality and gender inequality respectively. The World Bank's GDP/Capita adjusted for purchasing power parity was used as the measure of countries' wealth.Maternal biological factors (average women's height, total fertility rate and maternal age at first birth) and demographic factors (women's literacy rate and percentage of people living in urban settings) were mostly obtained from the DHS STATcompiler, with some few from the World Bank databases.Concentration curves and indices were used to measure and display the magnitude of inequalities in the distribution of anaemia and GAM across countries, when ranked by Human Development Index (HDI) and GII. Associations between GII and income inequality and anaemia and GAM were explored, separately, using linear regression. The associations were later adjusted for countries' wealth and maternal biological and demographic factors. A final multivariable model was constructed, each for anaemia and GAM, including all significant factors observed in the initial analysis.
Results: When ranked by GII, the prevalence distribution of both anaemia and GAM were highly unequal across countries, being higher and lower in countries with high and low GII scores respectively. A similar pattern was observed when ranking by HDI, with malnutrition prevalence concentrating more in countries with lower HDI scores. After adjusting for country's wealth level and maternal biological and demographic factors, GII showed a significant, independent and positive association with anaemia prevalence, explaining 50% of the variance between countries. The Gini index showed a significant, independent and negative association with GAM, explaining about 30% of the variance.
Conclusions: Gender inequality and/or low women's status in society may explain, independently, the high anaemia prevalence in many low- and middle-income countries. In contrast, poverty appears to be more important than income inequality for explaining GAM prevalence. Future analysis using a larger sample of countries, or using multilevel modelling for analysis, may provide further insights into the associations between wealth and inequalities and the global burden of malnutrition.

Introduction

Malnutrition and Anaemia

Malnutrition is a principal cause of disease and mortality in young children and remains a key issue in the Millennium Development Goals (MDGs) 1 and 4 (UN, 2000). In 2005, malnutrition affected an estimated 500 million children aged 5years or younger (Black et al., 2008) and was associated with more than half of deaths among this age group (Bryce et al., 2005). Poor countries of Asia and sub-Saharan Africa account for 80% of malnourished children (Bryce et al., 2008), with undernutrition responsible for 35% of disease burden in children under 5 years in these countries (Black et al., 2008). Undernutrition, used synonymously with malnutrition in this paper, is a spectrum of diseases that comprises acute malnutrition, stunting, underweight and deficiencies of essential micronutrients such as iron deficiency resulting in anaemia (*ibid*). Even within countries, malnutrition rates are higher among the poor (Wagstaff and Watanabe, 2000). Global acute malnutrition (GAM) results from short-term insufficiency of dietary nutrients (Wagstaff and Watanabe, 2000). GAM is diagnosed anthropometrically as a child having a weight-for-height z-score (WHZ) which is less than -2 standard deviations of the median weight-for-height of an international growth reference population, derived from the World Health Organization (WHO) (*ibid*). In 2009, GAM was estimated to have affected some 55million children younger than 5years of age in developing countries (Black et al., 2008). Anaemia is defined as a low haemoglobin concentration, red-cell count, or packed-cell volume such that there is inability to meet oxygen demands of the body (Warrell et al., 2003).

Anaemia may result from several factors, iron deficiency being the most important (Balarajan et al., 2012). Iron deficiency results when dietary iron intake is insufficient to meet iron demands of the body (*ibid*). Anaemia is a universal health problem affecting an estimated 1.62 billion people and 293million children of pre-school age globally (McLean at al., 2009). Expectedly, global burden of anaemia falls largely on countries of Asia and Africa, with the two continents accounting for greater than 85% of the total burden of anaemia in women of reproductive age and children (Balarajan et al., 2012). Children younger than five years are at high risk of anaemia as rapid growth during infancy requires increased iron intake (*ibid*). According to WHO, anaemia poses a moderate to severe public health problem in this age group about 80% of WHO member countries (de Benoist et al., 2008). Anaemia serves as an important deterrent to improving child health and thus achievement of MDG 4. It has been associated with several adverse health problems including neonatal mortality, low birth weight babies and poor cognitive development (Ezzati et al., 2004).

Inequality and Health

Inequality, as a deterrent to health and development, has been mentioned in almost all global Human Development Reports (HDR). Inequality in health undermines improvements in health and the achievement of the MDGs (ODI, 2010). There are different types of inequalities, but socioeconomic and gender inequalities are the most debated in the literature. Income inequality is often used as a measure of

socioeconomic inequality as it offers an alternative means of social class stratification in society (Wilkinson, 2006). Income inequality has been repeatedly linked to health status (Subramanian and Kawachi, 2004; Kondo et al., 2012; Ram, 2006). Some scholars claim that any effect income inequality has on health is mediated through poverty levels i.e. it is absolute income and not income inequality that matters (Lynch et al., 2004; Deaton, 2003). However, Wilkinson (1996) proposed the Income Inequality Hypothesis (IHH), arguing that income inequality directly affects health through the psychosocial stresses it places on people at the bottom of the socioeconomic ladder due to their deprivation status. According to Pickett and Wilkinson, income inequality will affect child wellbeing "through the effects of relative poverty on the level of material resources they are brought up with" (2007:6) The Gini coefficient, the most commonly used income inequality measure, has been extensively used to investigate the association between income inequality and health (Blakely et al., 2002; Subramanian et al., 2003; Wells et al., 2012). However, the focus of all these studies were highly developed countries and none looked at child malnutrition.
Gender equity is an inherent and essential part of development and the third MDG calls for the promotion of gender equality and female empowerment (UN, 2000). The UNDP's gender inequality report revealed that achievements in human development were greatly reduced by gender inequalities, especially in countries of South Asia, Sub-Saharan Africa and the Arab States (Gaye et al., 2010). Gender equality, used synonymously with women's status, has been defined as "women's power relative to men in the households, communities and nations in which they live" (Smith et al., 2003:5). Women's status has been linked to child undernutrition for more than 15 years. For instance, Smith and Haddad (2000) established that over a 25-year period, women's status and education contributed more than half of the decline in childhood underweight seen during this period. The effect of women's status on child nutrition is believed to be mediated through biological and social routes (Engle et al., 1999). Biologically, women's status is reflected in the adult height attained by the mothers, which in turn influences child's birth weight (Ozaltin et al., 2010). Low women's status may also lead to lower autonomy, early marriage, early and/or closely-spaced pregnancies and the corresponding poor health and nutritional outcomes for both mother and child (Raj, 2010; Raj et al., 2010). Socially, women's status will determine a number of factors which have already been linked to nutritional outcomes among children including women's control over household assets, decision-making, mobility, and freedom from domestic violence (Smith and Haddad, 2000; Shroff et al., 2009). Conversely, there are situations where improvement of women's status may not always be beneficial to child nutritional status. Women of a higher status are more likely to be educated, get formal jobs and spend less time on child care, leaving it in the hands of substitute caregivers. There is evidence that these substitute caregivers may not deliver as high a standard of care as the mother would (Leslie, 1998, Hobcraft, 2000). A rise in women's status may also increase conflict in the households, potentially putting women at increased risk of domestic violence which will be detrimental to their health and that of their children (Sen and Batliwala, 2000).

Economic Growth, Poverty and Malnutrition

At national level, economic growth has been linked to a reduction in the risk of childhood undernutrition (Smith and Haddad, 2002). Measures of economic development, such as GDP per capita, are strongly associated with child malnutrition and mortality in developing countries (Alderman et al., 2001) Economic growth may improve childhood nutrition through several pathways, including improving individual and household incomes and reducing poverty (Smith and Haddad, 2002). However, economic development may not always lead to a decline in levels of child undernutrition. In countries with high income inequalities, growth and development will only benefit the well-off and not the underprivileged members of society (Subramanyan et al., 2011). Moreover, it may be direct government investments in nutrition and public health rather than economic growth which reduce child undernutrition (Sen, 1999; Subramanyan et al., 2011).
Poverty is an established underlying cause of malnutrition, whilst malnutrition itself may exacerbate poverty (Weisstaub, 2008). Children from deprived households are much more prone to undernourishment compared to their wealthier counterparts (Van de Poel et al., 2008). Poverty can lead to child malnutrition in a number of ways including household food insecurity and poor environmental conditions such as housing, sanitation and access to safe drinking water (Menon, 2012), causing increased susceptibility to infectious diseases.

Maternal Biology, Demography and Malnutrition

A number of maternal characteristics have been linked with childhood nutrition. The intergenerational influences hypothesis (IIH), proposed by Emanuel (1986), suggests that malnutrition of the mother will have adverse consequences for the growth and development of her offspring. Maternal height is inversely related to childhood mortality and malnutrition (Varela-Silva et al., 2009; Monden and Smits, 2009). The effect of maternal height may be related to socio-economic circumstances, as height attained by the mother reflects conditions and resources she was exposed to in childhood (Sear et al., 2004). Maternal height may however be more related to chronic rather than acute malnutrition. Maternal age is positively associated with childhood nutrition and may serve as a proxy for the mother's accumulated experience in child healthcare. (Agee, 2010; Larrea and Kawachi, 2005). Delayed child birth also reduces the risks to mother and child associated with childbearing at too early an age. Repeated and frequent pregnancies place increased stress on the mother's nutrition and iron stores. Multiparity is thus linked with poor maternal nutritional status and maternal anaemia which are in turn related to poor child health and nutrition (Omar et al., 1994).
Women's education is vital for child nutrition, health and survival (Armar-Klemesu et al., 2000). Maternal education may directly improve childhood nutrition as educated women will more likely exhibit positive child-caring behavior and more easily and frequently access health facilities (Smith et al, 2005). Women's education may also delay child bearing (Boyle et al, 2006), giving women more time to grow and achieve a better nutritional status, thus improving both maternal and child nutrition. Furthermore, educated mothers have more opportunity to get better jobs and contribute to

household income and wealth, which are both determinants of child nutrition (*ibid*).
Evidence from the literature suggests that urban children are usually better nourished than their rural counterparts (Smith et al, 2005). Urban environment is thought to offer greater food availability and variability in diet, as well as more access to health facilities and employment opportunities (*ibid*).

Current Evidence gaps and Project Justification
Despite several studies linking income inequality and health (Van Ourti et al., 2009; Pickett and Wilkinson, 2008; Kondo et al., 2012), most of these studies have been restricted to developed countries. They usually also focused on mortality and self-rated health, and not malnutrition.
Although studies have looked into the effect of socioeconomic inequalities on malnutrition in developing countries (Wagstaff and Watanabe, 2000; Van de Poel et al., 2008), the majority of these studies assessed stunting and underweight. Smith and colleagues (2005) only looked into rural/urban socioeconomic differences in childhood wasting and stunting among children in 37 developing countries.
This study targeted the potential contribution of inequalities to two different types of malnutrition- GAM and micronutrient deficiency in the form of anaemia. It will be of interest to compare how developing countries fare in the average rates of these often neglected but persistent nutritional problems and the extent of economic and gender inequalities. By controlling for economic, biological and demographic factors, this study aimed to indicate whether inequalities independently influence these nutritional outcomes irrespective of other well-known determinants of nutrition. It is also aimed at expanding our understanding about the role socioeconomic and gender inequalities have on anaemia and GAM, and about their potential independent contribution. The study may help give an understanding into why certain countries are not on track to achieve MDGs 1, 4 and 5.

Aims and Objectives
This study aimed to assess the relationship between economic and gender inequalities and nutritional indicators of children younger than 5years in low- and middle-income countries.
Specific Objectives included:

- To build the dataset necessary to answer the research question.
- To evaluate the relationships between economic and gender inequalities and anaemia in children under 5years of age.
- To evaluate the relationships between economic and gender inequalities and GAM in children under 5 years of age.
- To determine whether the relationships between the inequalities and nutritional indicators are modified by a country's level of economic development, maternal biological or demographic factors.

Methods
This was an ecological study looking into the associations of economic and gender inequalities and childhood malnutrition in low- and middle-income countries. The dataset was collated from a number of sources. These sources were all in the public domain and are freely available, so permission to obtain the data and ethical approval was not required. Table 1 below gives a list of all the variables and their sources.

Table 1: List of Variables and their Sources

Variable	Source
Anaemia	DHS & WHO (de Benoist et al., 2008)
GAM	DHS & UNICEF-WHO-the World Bank (2012)
Gini Index	World Bank
Gender Inequality Index (GII)	UNDP (2013)
GDP/capita PPP	World Bank (2011)
Poverty Gap	World Bank
Total Fertility Rate (TFR)	DHS & World Bank
Average Women's Height	DHS
Maternal Age at First Birth	DHS
Women's Literacy Rate	DHS
Urban Population Percentage	DHS & World Bank

The data were mostly from DHS and the World Bank. The DHS surveys are conducted in developing countries and provide nationally-representative data and are one of the best sources of nutritional data from developing countries (Smith et al., 2005). The data are generally comparable across countries as similar methodologies are employed in the survey and data collection. When DHS data were unavailable, data were supplemented from UNICEF, WHO and the World Bank.
The Gini coefficient, the income inequality measure, has the advantage that it measures inequality across the whole range of income. In theory, it ranges from 0 when income is evenly distributed in the population (absolute equality) to 1 when one person has all the income (absolute inequality) (Blakely et al., 2002). Gender inequality is assessed using the UNDP's new Gender Inequality Index (GII). The GII is an important improvement on previous measures of gender equality (Gaye et al., 2010). It measures the disadvantages faced by women in three areas- empowerment, economic activity and reproductive health, and reveals the extent by which a country's development potential is reduced by gender inequality (*ibid*). The GII value ranges from 0 (no gender inequality) to 1(total gender inequality). More details can be obtained elsewhere about the calculation of the Gini coefficient (Lerman, 1984) and the GII (Gaye et al., 2010).
The GDP/capita and poverty gap are used as measures of development instead of the HDI. This is because the HDI is a composite index which includes data on education, increasing

the likelihood of endogeneity with one of the variables- women's literacy rate. The GDP/Capita is measured in US dollars and adjusted for purchasing power parity (PPP), making it comparable across countries. The poverty gap is used to measure the amount of people living below a determined poverty line. The international poverty line, $1.25 per day, is selected for this study because although it may not reflect true poverty in some countries, it is more comparable across countries.

55 developing countries from Africa, Asia, Eastern Europe and Latin America were selected for having DHS data published in the year 2000 and after. Every country selected had data for at least one of the outcome variables, anaemia or GAM in children under 5years, and data for at least one measure of inequality. Only a few countries did not have data for GAM (3 countries) and the GII (5 countries). Data management and main analyses were done using Stata IC (version 11). Data were initially recorded using Microsoft Excel and later exported to Stata. Each variable was assessed for normality using histograms to visually examine distributions. When the variables were not normally distributed, the gladder and ladder Stata commands were used to determine the best transformation.

Firstly, the potential association of inequalities and malnutrition were assessed by evaluating the distribution of malnutrition in the total population using concentration curves and indices. The concentration curve provides an easy way of displaying these inequalities. The further away the curve lies from the diagonal (line of equality), the greater the inequality in the distribution of the outcome being measured (ibid). This inequality can be quantified by calculating the concentration index which varies between -1 and +1 and is defined as twice the area between the concentration curve and the line of equality (Wagstaff and Doorslaer, 2004). The concentration index has certain characteristics that make it a good measure of inequality: it reveals the socioeconomic aspects of health inequalities, captures the experience of the entire population and is sensitive to changes in population distribution (Zere and McIntyre, 2003). Concentration curves were plotted for both anaemia and GAM. The countries were used as individual units and ranked according to the HDI and GII, starting from the lowest values. All countries in the sample were included, except for Sri Lanka, which lacked data for the population of children under 5 years of age. HDI is chosen over GDP/capita for the economic ranking because it is a better representation of a country's level of economic development since it measures both the income and non-income aspects (UNDP, 2013). It is based on life expectancy, education and GDP/capita and ranges from 0 (no human development) to 1 (maximum human development) (*ibid*).

Crude associations between explanatory variables and outcomes (GAM and anaemia) were visually and statistically tested using scatter plots and correlation analysis respectively. The analysis was carried out using the analytical framework given in figure 1 below. Firstly, univariable associations between explanatory variables and outcomes were investigated separately using linear regression. This is an ecological study, thus causal relationship cannot be inferred from the associations observed between exposure and outcome variables. Therefore, bivariable analyses were carried out to test the effect of potential confounders on the observed associations between main exposure variables and outcome. Factors considered as potential confounders included measures of economic development, maternal biological features and demographic factors. These factors were selected from the literature as those which influence childhood malnutrition and may be potentially associated with inequality. Subsequently, multivariable analyses were carried out to test associations between exposure variables (GII and Gini) and outcomes, whilst adjusting for all potential confounders simultaneously. Variables were included in the final models if they were independently associated with the outcomes at $p<0.05$.

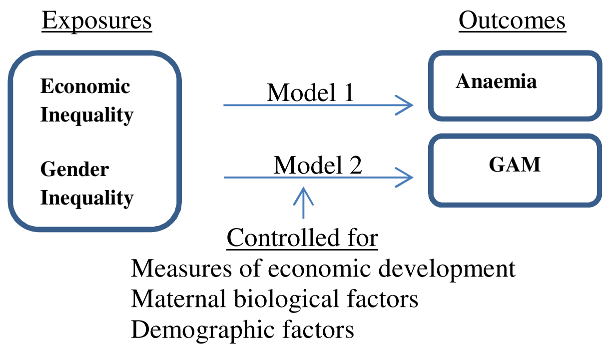

Figure 1: Analytical Framework investigating the associations between Economic and Gender Inequality and Nutritional Outcomes. Measures of economic development: GDP/capita PPP and Poverty Gap. Maternal biological factors: TFR, maternal age at first birth and average women's height. Demographic factors: women's literacy rate and percentage of population living in urban area.

Results

55 developing countries were chosen on the basis of having DHS data published in year 2000 and after and data for one or both inequalities (Gini and/or GII). Using the World Bank income group classification of countries, 23 of the countries were low income, 24 were lower middle income and 8 were higher middle income countries (Table 2). All 55 countries had data for the Gini and anaemia in children under 5years. 52 countries had data for GAM prevalence and 50 had data for the GII. Table 3 below gives a summary of the data.

Table 2: World Bank Income Group Classification of Countries, by GDP/capita PPP

Low Income (≤ $1025)	Lower Middle Income ($1026-$4035)	Higher Middle Income ($4036-$12475)
Bangladesh	Albania	Azerbaijan
Benin	Armenia	Columbia
Burkina Faso	Bolivia	Dominican Republic
Burundi	Cameroon	Gabon
Cambodia	Congo Republic	Jordan
Chad	Egypt	Maldives
Democratic Republic of Congo (DRC)	Ghana	Namibia
Ethiopia	Guyana	Peru
Haiti	Honduras	
Kenya	Indonesia	

Liberia	India	
Madagascar	Lesotho	
Malawi	Moldova	
Mali	Morocco	
Mozambique	Nicaragua	
Nepal	Nigeria	
Niger	Pakistan	
Rwanda	Philippines	
Sierra Leone	Senegal	
Tanzania	Sri Lanka	
Timor Leste	Swaziland	
Uganda	Ukraine	
Zimbabwe	Vietnam	
	Zambia	

Table 3: Summary of Data. N: number of observations. SE: standard error of the mean. 95% CI: confidence interval at 95% significance level

Variable	N	Mean	SE	95% CI
Anaemia	55	52.5	2.5	47.4 to 57.5
Wasting	52	8.1	0.7	6.7 to 9.5
Gini	55	41.3	1.15	39 to 43.6
GII	50	0.5	0.02	0.5 to 0.6
GDP/capita PPP	55	2239	3001	1636 to 2841
Poverty Gap	52	31.9	3.6	24.5 to 39.2
TFR	55	4	0.2	3.6 to 4.4
Maternal Age at First Birth	55	20.7	0.2	20.3 to 21.2
Average Women's Height	49	157	0.5	156 to 158
Women's Literacy Rate	46	65.3	3.7	57.8 to 72.9
Urban Population Percentage	55	40.5	2.5	35.4 to 45.5

Distribution of Anaemia and GAM across Countries
When ranked by the HDI, the overall distributions of both nutritional outcomes are unequal, in favor of the countries with a higher HDI (**Fig. 2**). With anaemia, this is seen across the whole spectrum of countries with countries with low HDI bearing a greater burden of anaemia compared to those with higher HDI (concentration index = -0.12). In contrast, the distribution of GAM is more equal for countries with low HDI, but becomes unequal for those with higher HDI where the curve crosses the line of equality (concentration index= -0.07).

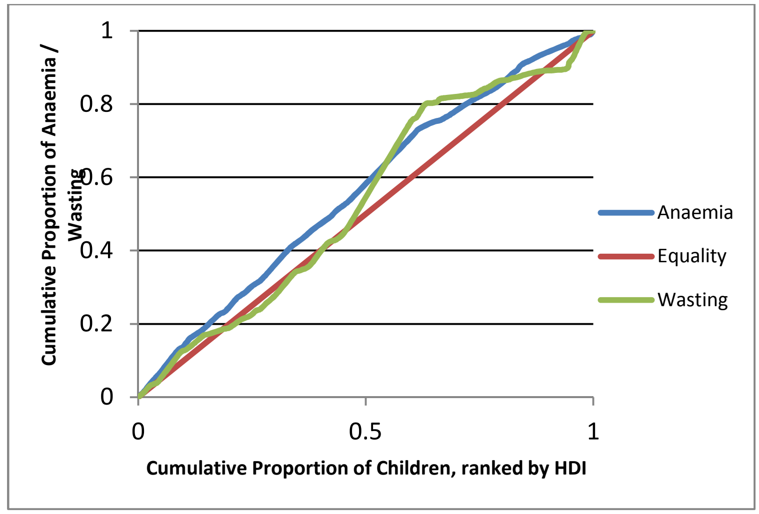

Figure 2: Concentration Curve for the distribution of anaemia and GAM across countries, ranked by the HDI, starting with lowest and ending at highest.

To assess the pure economic inequality in the distribution of malnutrition across these countries, the concentration curves were also plotted for each outcome with countries ranked by GDP/capita PPP. There was greater burden of anaemia among the poorer countries, whilst GAM was approximately equally distributed across the countries, with concentration indices of -0.08 and 0.01 respectively (see appendix 1).
When countries are ranked by the GII, the distribution of both anaemia and GAM are highly unequal, with countries with the highest GII scores accounting for much more of the burden of these nutritional problems relative to those with lower GII scores (**Fig.3**). The distribution of GAM is more unequal than that of anaemia and the corresponding concentration indices are 0.23 and 0.14 respectively.

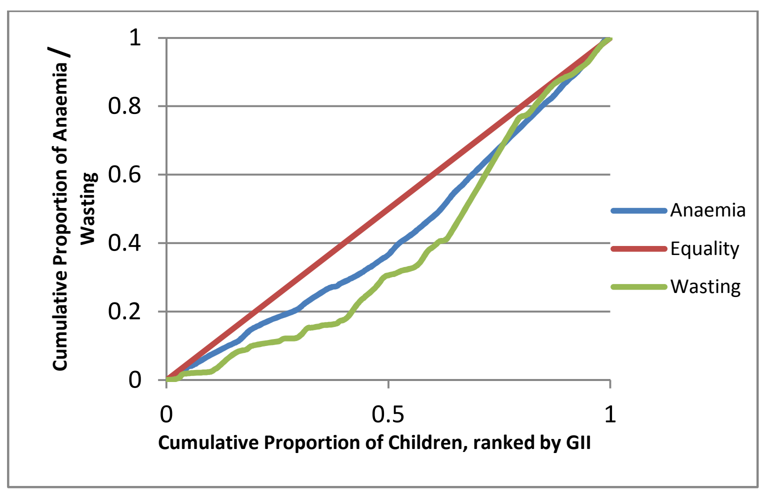

Figure 3: Concentration Curve for the distribution of anaemia and GAM across countries, ranked by the GII, starting with lowest and ending at highest.

Variables Distributions and Transformations
The outcome variables are anaemia and GAM in children under 5 years of age and the main exposure variables were GII and Gini. The distributions of all variables were assessed for normality. Most of the variables were kept in the original

format since they were either approximately normally distributed or there was no gain in normality from transformation. Two variables (gini and GDP/capita) were transformed to achieve best normal fit, which was given by a natural logarithm transformation. There was no best normal fit for women's literacy rate. Transforming this variable (women's literacy rate) into a categorical variable was considered to deal with this problem. On the other hand, due to the risk of losing valuable information when the data is grouped, the original format of the variable was retained for analysis. Some graphical examples of the distribution and transformation of the variables are given in appendix 2.

Outcome Data

Correlation Analyses

Associations of Anaemia with Inequalities

There was evidence of a positive linear association between the GII and anaemia (r=0.7, p=<0.01). Conversely, there was no evidence of an association between Lngini and anaemia (r=0.04, p=0.08). Figure 4 below gives the graphical representations of these associations.

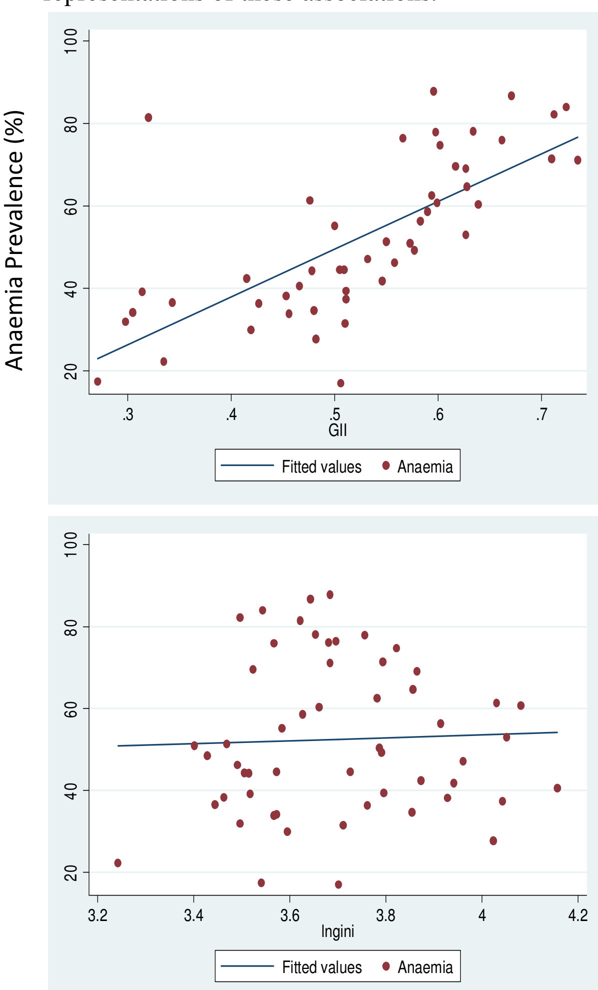

Figure 4: Scatterplots showing the associations of anaemia with Gender Inequality Index (GII) and Gini Index (Lngini: natural logarithm of the Gini index).

Associations of GAM with Inequalities

There was evidence of a positive linear association between GII and GAM (r=0.3, p=0.048). LnGini was negatively correlated with wasting (r=-0.53, P=<0.01) (**Fig.5**).

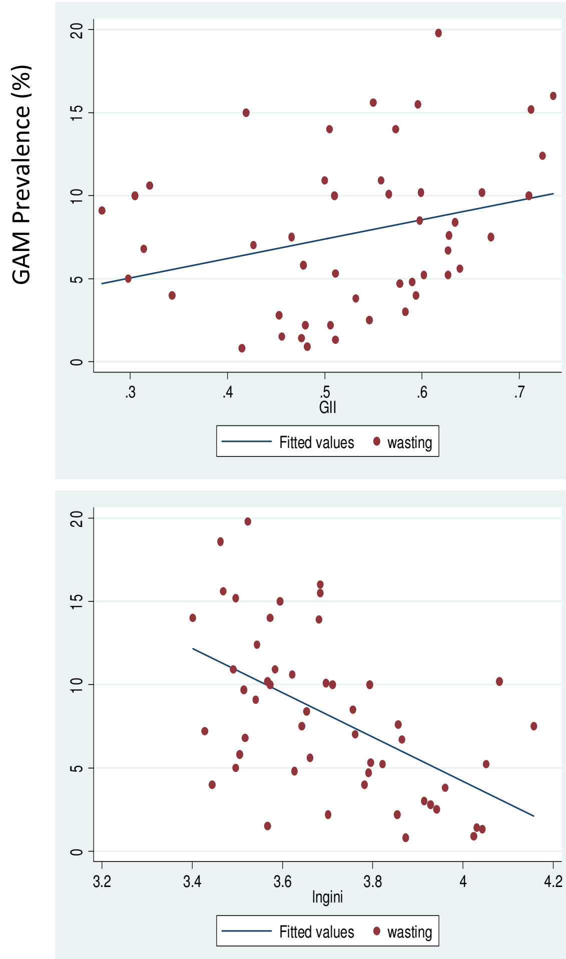

Figure 5: Scatterplots showing the associations of GAM with GII and the Gini Index (LnGini: Natural log of Gini Index)

Table 4: Correlation of Variables. The numbers given are the correlation coefficients. Maternal age is at first birth. Women's Height: Average. Lngini: Natural logarithm of Gini index. Lngdp: Natural Logarithm of GDP/capita PPP.

Explanatory Variables	**Outcome Variables**		**Explanatory Variables**							
	Anaemia	GAM	GII	Ln Gini	Ln GDP	Poverty Gap (%)	TFR	Maternal Age	Women's Height	Women's Literacy Rate (%)
GII	0.7ł	0.3*								
Ln Gini	0.0	-0.5ł	0.2							
Ln GDP	-0.5ł	-0.2	-0.6ł	0.1						
Poverty Gap	0.5ł	0.1	0.7ł							
TFR	0.7ł	0.2	0.8ł	0.1	-0.7ł	0.8ł				
Maternal Age	-0.6ł	-0.1	-0.7ł	-0.1	0.5ł	-0.5ł	-0.6ł			
Women's Height	0.2	0.03	0.1	-0.1	0.0	0.1	0.3*	-0.1		
Women's Literacy rate	-0.7ł	-0.6ł	-0.7ł	0.5ł	-0.6ł	-0.4*	-0.7ł	0.5ł	-0.3	
Urban Population	-0.3*	-0.5ł	-0.2	0.2	0.7ł	-0.5ł	-0.4ł	0.3	0.1	0.3*

* $p<0.05$; ł $p< 0.01$

Table 4 above gives the results of the correlation analyses. It is evident that Ln GDP/capita was significantly associated with anaemia but not with GAM. Of the 3 biological factors being analyzed, anaemia was significantly associated with TFR and maternal age at first birth, but not with average women's height. There was no evidence of an association between GAM and all 3 biological variables. Anaemia and GAM were both negatively associated with the two demographic variables (women's literacy rate and urban population percentage) and the associations were statistically significant.

Correlation Analyses between other Explanatory Variables

The associations between other explanatory variables were also explored to identify highly correlated variables and thus minimize the potential of multicollinearity in the final models. There was evidence of a strong correlation between LnGDP/capita and poverty gap (**Table 4**). As expected, from individual correlation analysis performed, both GDP/capita and poverty gap behave in the same way with all other variables, albeit in different directions. Therefore poverty gap was removed from the analysis from this stage onwards.

Regression Analysis

Anaemia: Univariable Regression Analysis

Univariable analysis revealed significant associations of anaemia with GII, Ln GDP/capita, poverty gap, TFR, maternal age at first birth, women's literacy rate and urban population percentage (**Table 5**). The R-square values give the percentage of variability in anaemia that is explained by each variable; for instance, 50% of the variability in anaemia is explained by the GII whilst none is explained by Ln Gini.

Table 5: Univariable Analyses of Anaemia with inequalities, measures of economic development, maternal biological and demographic factors. N: number of observations; β: regression coefficient; t: value of t-test; R^2: R-square.

	Variable	N	β	95% CI	t	R^2
Anaemia	GII	50	116ł	82 to 150	7.0	0.5
	Ln Gini	55	3.6	-22 to 29	0.3	0.0
	Ln GDP/capita	55	-9.5ł	-14 to -4.9	-4.1	0.2
	Poverty Gap	52	0.4ł	0.2 to 0.6	4.5	0.3
	Average Women's Height	49	1.0	-0.6 to 2.6	1.2	0.0
	Maternal Age at First Birth	55	-0.7ł	-9.7 to -4.4	-5.3	0.4
	TFR	55	7.8ł	5.3 to 10	6.2	0.4
	Women's Literacy Rate	46	-0.5ł	-0.7 to -0.3	-6.5	0.5
	% Urban Population	55	-0.3*	-0.6 to 0.0	-2.9	0.1

ł $p<0.001$
*$p<0.05$

Anaemia: Bivariable Analysis

The association between anaemia and GII may be potentially confounded by GDP/capita, maternal age at first birth, TFR, women's literacy and urban population percentage. After controlling for one potential confounder at a time, the association between anaemia and GII was altered, but remained statistically significant (**Table 6**).

Table 6: Bivariable analysis of association between anaemia and GII, controlling for potential confounders individually. β: regression coefficient; t: value of t-test; R^2: R-square.

Variable	β		95% CI	t	R^2
Observed GII	116*		82.4 to 149	7	0.5
Controlled for		Adjusted β			
TFR	75 *		21.4 to 129	1.9	0.5
Women's Literacy	101*		53.8 to 149	-2.6	0.7

*$p<0.05$

Anaemia: Multivariable Analysis

The potential confounders were put into the regression model simultaneously, the order determined by the strength of their associations with the outcomes already determined in univariable analysis. For anaemia, the order was lnGDP/capita, TFR, maternal age at first birth, women's literacy rate and urban population percentage.

The association between anaemia and GII was altered by controlling for women's literacy rate remained significant ($p<0.001$) (**Table 7**). All other potential confounders did not fit the model since the p-value for their F-tests is greater than 0.05; thus they were removed from the final model.

Table 7: Multivariable Analysis for Association of Anaemia and GII, controlling for all potential confounders. β:regression coefficient; t: value of t-test; R^2: R-square**.**

Exposure	β	95% CI	t	R^2
No adjustment GII	116*	82.4 to 149	7	0.5
Adjusted for				
GII	101 *	53.8 to 149	6.4	0.7
Women's Literacy	-0.2*	-0.4 to -0.1	-2.6	

*$p<0.05$

GAM: Univariable Regression Analysis

Univariable analysis revealed significant associations of GAM with GII, Lngini, women's literacy rate and urban population percentage (**Table 8**).

Table 8: Univariable Analyses of GAM with inequalities, measures of economic development, maternal biological and demographic factors. N: number of observations; β: regression coefficient; t: value of t-test; R^2: R-square.

	Variable	N	β	95% CI	t	R^2
GAM	GII	48	11.7*	0.1 to 23.3	2	0.1
	Ln Gini	52	-13.3ł	-19.3 to -7.3	-4.5	0.3
	Ln GDP/capita	52	-1.3	-2.8 to 0.1	-1.8	0.1
	Poverty Gap	49	0	0 to 0.1	1.1	0
	Average Women's Height	47	0	-0.4 to 0.5	0.1	0
	Maternal Age at First Birth	52	-0.3	-1.1 to 0.6	-0.6	0
	TFR	52	0.6	-0.3 to 1.5	1.3	0
	Women's Literacy Rate	45	-0.1ł	-0.2 to -0.1	-4.8	0.3
	% Urban Population	52	-0.1ł	-0.2 to -0.1	-3.8	0.2

ł $p<0.001$
*$p<0.05$

GAM: Bivariable Analysis
The association of GAM with both inequalities may be potentially confounded by women's literacy rate and urban population percentage.
After controlling for women's literacy and urban population percentage separately, the association between GAM and GII was no longer significant (**Table 9**).

Table 9: Bivariable Analysis: GAM and GII controlling for potential confounders individually. β: regression coefficient; t: value of t-test; R^2: R-square

Variable	β		95% CI	t	R^2
Observed					
GII	11.7*		0.1 to 23.3	2	0.1
Controlled for		**Adjusted β**			
Women's Literacy	-5.2		-22.2 to 11.7	-0.6	0.4
Urban Population	7.8		-3.1 to 18.6	1.4	0.3

*$p<0.05$

After controlling for one potential confounder at a time, the association between GAM and Lngini statistically significant (**Table 10**). Both women's literacy rate and urban population were significantly associated with GAM when Lngini is held constant ($p<0.01$).

Table 10: Bivariable Analysis: GAM and Lngini controlling for potential confounders individually. β: regression coefficient; t: value of t-test; R^2: R-square.

Variable	β	95% CI	t	R^2
Observed				
Lngini	-13.3	-19.3 to -7.3	-4.5	0.3
Controlled for	**Adjusted β**			
Women's Literacy	-10.4*	-16.5 to -4.3	-3.4	0.5
Urban Population	-10.9*	-16.6 to -5.9	-3.9	0.4

*$p<0.01$

GAM: Multivariable Analysis
The potential confounders were put into the regression model simultaneously, the order determined by the strength of their associations with the outcomes already determined in univariable analysis. For GAM, the order was urban population percentage and women's literacy rate. After controlling for women's literacy rate, the association between GAM and GII was no longer significant ($p=0.535$) (**Table 11**). Urban population percentage did not fit the model since the p-value for the F-test is greater than 0.05; thus it was removed from the final model.

Table 11: Multivariable Analysis for Association of GAM and GII, controlling for all potential confounders. β: regression coefficient; t: value of t-test; R^2: R-square**.**

Exposure	β	95% CI	t	R^2
No adjustment				
GII	11.7*	0.1 to 23.3	2	0.3
Adjusted for				
GII	-5.2	-22.2 to 11.7	6.4	0.4
Women's Literacy	-0.1*	-0.2 to -0.1	-2.6	

*$p<0.05$

The association between GAM and Lngini was altered by controlling for women's literacy rate (**Table 12**). Even though the β coefficient reduced from -13.3 to -10.4, the association remained statistically significant ($p<0.01$). Urban population percentage did not fit the model since the p-value for the F-test is greater than 0.05; thus it was removed from the final model.

Table 12: Multivariable Analysis for Association of GAM and LnGini controlling for all potential confounders. β: regression coefficient; t: value of t-test; R^2: R-square**.**

Exposure	β	95% CI	t	R^2
No adjustment				
Ln Gini	-13.3ł	-19.3 to -7.3	-4.5	0.3
Adjusted for				
Ln Gini	10.4ł	-16.5 to -4.3	-3.4	0.5
Women's Literacy	-0.1ł	-0.1 to -0.03	-3.3	

ł $p<0.01$

Discussion
Key Findings
Anaemia and GAM were more concentrated among countries with high gender inequality compared to those with lower gender inequality. Countries with low human development also had a higher burden of anaemia relative to their more developed counterparts. On the other hand, GAM was equally distributed among the countries with the lowest HDI values, but less equally among those with higher HDI.

Anaemia was strongly associated with GII even after adjusting for potential confounders such as women's literacy rate and urban population percentage. Every 0.1 unit increase in GII

resulted in a 10% increase in anaemia prevalence. There was no association between anaemia and the gini index.
In contrast, the prevalence of GAM was associated with both GII and the gini index. After controlling for possible confounders, only the association with the gini index remained significant, with every 1 unit increase in Lngini resulting in a 10.4% reduction in GAM prevalence.

Interpretation of the key findings

Anaemia was strongly related to gender inequality, even after controlling for possible confounders. The concentration curve displays the unequal distribution, clearly showing that the burden of anaemia was concentrated among those countries with high gender inequality. There are no known studies in the literature addressing this issue. Gender inequality appeared somewhat related to average income, which could explain some of its relation to anaemia, since the link between anaemia and income has already been established (Balarajan et al., 2012). However, controlling for income did not significantly change the association between anaemia and GII. Women's status is an important determinant of maternal and subsequently child nutrition and health (Smith et al., 2003). In countries with low gender equality, women have less autonomy with regards to decisions about child-bearing and rearing (Raj et al., 2010). This may result in early-onset child-bearing, more children and closely-spaced pregnancies (Upadhyay and Hindin, 2005), all risks for development of maternal anemia. Several studies have already confirmed the link between maternal anaemia and anaemia in children (Kalaivani, 2009; Meinzen-Derr et al., 2006; Balarajan et al., 2012), and the possibility of an intergenerational transfer of anaemia from mother to child. This link could also socioeconomic-based, with children of mothers who lack access to a micronutrient-rich diet being likely to suffer the same predicament. This relationship between women's status and child nutrition is supported by the fact that both gender inequality and anaemia were directly related to TFR and maternal age at first birth from our analysis. As expected, a higher TFR was associated with higher rates of anaemia. This finding is consistent with Omar et al. (1994) who reported that multiparity in Somali women was related to maternal anaemia and consequently to poor child health. There may be several explanations for this finding. To start with, frequent and multiple childbirths put additional stress on women and deplete their body iron stores (Balarajan et al., 2012). Furthermore, these women are at increased risk of complications such as bleeding during pregnancy, thus predisposing them to anaemia. In addition, having too many children to care for, especially under poor circumstances, means less food and resources are available to each child. Finally, these women often do not have help in looking after children and have to do all the household chores at the same time, meaning less time spent on safe child care practices.
As anticipated, countries where women started child-bearing at a later age had lower levels of anaemia. This is in agreement with Larrea and Kawachi (2005) who postulated that maternal age may act as a proxy for good child caring experience that has been amassed over the years. They also proposed that deterring childbirth will protect both mother and child from complications associated with pregnancy at too early an age. Not surprising though is that maternal age is not related to acute malnutrition. As has already been suggested, the determinants of acute malnutrition are to some degree different from those of anaemia and chronic malnutrition.

The association between GII and women's literacy rate may also explain to some extent the relationship between gender inequality and anaemia. Women with little or no education are more likely to have low status and lack autonomy (Mason, 1986). This study found that anaemia was inversely related to women's literacy rate. A similar finding was reported by Balarajan et al. (2012) who analyzed DHS data from 32 low- and middle-income countries and found that the risk of anaemia was higher among children whose mothers had no education. The importance of maternal education for child nutrition cannot be emphasized enough. Women with formal education are more likely to practice safe and effective child caring and feeding practices, more frequently access health services and better understand health education and promotion programs (Smith et al., 2005; Porter et al., 2010). Also, maternal education deters early child-bearing and frequent pregnancies, both established risk factors for maternal and child anaemia (Boyle et al., 2006).

The lack of an association between anaemia and income inequality, as indexed by the gini, was unexpected. This is in contrast to the findings of Larrea and Kawachi (2005), who reported an association between income inequality and malnutrition in Ecuador. However, their results were limited to one country and they focused on stunting, not anaemia. There may be several explanations for this finding. Firstly, like other measures of inequality, the gini index typically measures inequalities in officially reported incomes (Rosser et al., 2000). In most developing countries however, a substantial part of the economy is informal, and income from this is often unreported and difficult to measure (Chambwera et al., 2000). Thus, income from this informal economy is likely not included in calculations of the gini index. This informal sector provides employment for the poorest and most vulnerable people, especially women (*ibid*). In contrast, the formal workforce in these countries is normally dominated by the male population. It is thus possible that the gini index in developing countries takes into account mostly male incomes. Although anaemia may be a universal problem in some countries, it is mostly women and children who are at increased risk (Balaranjan et al., 2012). This may explain the lack of association between anaemia and the gini index and the strong association with the GII. Compared to men, women are at higher risk of anaemia and maternal anaemia is linked to childhood anaemia (*ibid*). As a result, anaemia in children will be more related to the GII which specifically measures inequalities women are subjected to. That the gini index may not reflect a true inequality faced by women in low- and middle income countries is an interesting concept that requires further investigation.

In this study, GAM was related to the GII, but the association was much weaker than that between anaemia and GII and became insignificant after controlling for women's literacy rate. This is probably because GAM, a manifestation of acute malnutrition, is usually precipitated by unforeseen environmental factors and diseases (Wagstaff & Watanabe, 2000). Like other forms of inequality, gender inequality subjects women and female children to long-term and sustained disadvantages in life, thus predisposing them to chronic rather than acute malnutrition. Gender inequality is also possibly linked to childhood malnutrition through its effect on maternal health and nutrition. Most studies linking maternal malnutrition to childhood malnutrition found positive effects for chronic malnutrition such as stunting and underweight (Bhalotra & Rawlings, 2011; Varela-Silva et al., 2009). This is because the environmental and socio-economic factors implicated in the development of maternal malnutrition and chronic malnutrition in children, differ somewhat from those thought to result in acute malnutrition.

Surprisingly, the results of this study suggested that GAM prevalence was lower in countries with higher income inequality. There may be several explanations for this finding. Firstly, only developing countries were included in this study. It has been suggested whilst income inequality matters for rich countries, it is absolute income that determines population health in poorer countries (Wilkinson, 1996; Ram, 2006). Secondly, among these countries, some of the highest levels of inequality were experienced by Latin American countries (LACs). Meanwhile, with the exception of Haiti, these same countries were all middle income countries, had the lowest rates of GAM, highest urbanization rates and higher rates of women's literacy. Urbanization has been linked to better child nutritional status (Smith et al., 2005). Urban environment may offer access to a better and more variable diet (*ibid*) and better employment opportunities and consequently more income for families. Additionally, in developing countries, health staff and facilities tend to be more concentrated in urban areas compared to rural areas (Wilson et al., 2009). The positive link between maternal education and child nutrition has already been discussed. Finally, figures for the gini are generally more recent than those of wasting, sometimes by as much as 5years. From the literature, it is known that income inequality has a lag effect on health, and may exert the most effect on health up to 15years later (Blakely et al., 2000; Subramanian & Kawachi, 2004). Therefore, this association may not reflect the true current situation.

Other Findings

The concentration of anaemia among low income countries compared to their higher income counterparts is an expected finding. People in poorer countries are much more likely to lack access to a micronutrient-rich diet, which often predisposes them to iron deficiency, the commonest cause of anaemia (Balarajan et al., 2012). The poor diet may well be a direct result of poverty and corresponding food insecurity, or it could result from an inability to access the right food groups from the markets, either due to food shortages or poor nutritional knowledge. Also, low income countries generally have low government spending on public health programs, such as nutritional campaigns, which may act as deterrents to malnutrition. Pathak and Singh (2011) found that childhood malnutrition was lower in Indian states that spent more money on nutritional programs compared to other states.

Women's height was not related to both our nutritional outcomes. This is surprising since numerous studies have repeatedly linked maternal height to nutritional status of the mother and her child (Monden and Smits, 2009; Subramanian et al., 2009). Attained adult height is seen as a socio-economic indicator of the conditions the mother was exposed to during childhood (Sear et al., 2004), which may thus be transferred to her child. Shorter women are also at increased risk of giving birth to LBW children, an independent risk factor for both acute and chronic malnutrition (Fernandez et al., 2002). Shorter women face more risks of complications during pregnancy such as bleeding, which predisposes them and their children to anaemia. The lack of an association between women's height and childhood nutritional status may be because this study utilizes aggregate data for height, otherwise an individual level characteristic.

Predictably, urban residence was positively associated with both anaemia and GAM, consistent with the findings of Smith et al. (2005). They conducted an ecological study of 36 developing countries and found that nutritional status of urban children was undeniably better than those living in rural areas. The mechanism through which urban population may lead to better nutritional status of children has already been discussed in the previous section.

Women's literacy rate was also negatively related to both anaemia and wasting. Of all the possible confounders considered in this study, it was the only factor that was independently associated with both nutritional outcomes after correcting for the effect of inequalities. This finding further highlights the importance of maternal education to child nutritional status and is consistent with several studies addressing this issue (Smith et al., 2005; Boyle et al., 2006).

Sensitivity Analyses

Six countries in the sample accounted for over 10% of the total under-fives population, each with a population of over 100,000 (Malawi, Nigeria, Indonesia, India, Dominican Republic and Columbia), and with the exception of Malawi, were all middle-income countries. To check whether this affected the results of the study, sensitivity analysis was performed without these 6 countries. Malnutrition was still concentrated in the countries with the higher gender inequality scores, although GAM became much less unequal with the concentration index decreasing from 0.23 to 0.15. When ranked by HDI, the distribution of anaemia stayed the same (concentration index= -0.12). However, GAM became more unequally distributed, with countries with low HDI carrying a greater burden of acute malnutrition compared to their more developed counterparts (concentration index changed from -0.07 to -0.15) (**Appendix 3**). From the analysis, the direction and significance of the association between gender inequality and anaemia and that between income inequality and GAM did not change.

Limitations

This study has the usual limitations of ecological studies, in that it uses aggregate data to explain the association between inequalities and malnutrition. Health is an individual variable and the use of aggregate data may not reflect true associations between inequality and individual health (Subramanyan et al., 2011). Because of the ecological nature of this study, the results are not necessarily applicable to smaller geographical units or individuals. Another limitation is that our variables are from different periods, which may affect the results. However, the most recent data for each country has been employed in this analysis, and all date from the year 2000 and onwards. Although significant associations between inequalities and malnutrition were revealed, this study is a cross-sectional one and so cannot ascertain causality. Nevertheless, our results cannot be easily attributed to confounding. Also, it is unlikely that anaemia, for instance, leads to gender inequality and not the other way around.

Another thing of note is that the aetiology of anaemia is also multifactorial. Iron deficiency, which is most commonly linked to socioeconomic or women's status, accounts for only about 50% of anaemia. There are several other determinants of anaemia prevalence in developing countries, including genetic factors and malaria endemicity. Additionally, a lot of the countries in this sample have, at one time or the other, had a civil war, which itself can lead to food shortages and increased rates of poverty, both risk factors for malnutrition. All these factors were not taken into account in the analysis and may otherwise affect the results of the study.
Moreover, this study cannot determine what percentage of childhood anaemia is linked to maternal anaemia. More studies are required to disentangle the relationship between anaemia in women and childhood anaemia; this may lead to a better understanding of the link between gender inequality and anaemia in children.
Finally, the concentration curve illustrates inequalities across the countries, but does not show within-country inequalities, which are also important for policy makers.

Strengths
Despite its limitations, it is the first study to show evidence of a cross-country association between anaemia and gender inequality in developing countries. The construction of the concentration curve provides an easy way of graphically displaying this gender inequality of anaemia across countries. It is also the first ecological study looking at the effects of gender and income inequality on childhood malnutrition. It employs data from 55 countries from different regions of the world, making the results largely generalizable to all low and middle-income countries. The study also uses DHS data for health variables which makes them comparable across all countries.

Conclusion
This study enables us to come closer to understanding the ultimate causes of GAM and anaemia. The proximate causes are well known but it is important to understand contextual factors if effective policy is going to be made. For instance, it is known that GAM is closely linked to environmental circumstances, such as hygiene, prevalence of infectious diseases and the availability of medical attention. However, this study suggests that poverty at the national level, and not income inequality, may be its ultimate cause. In fact, Latin American countries with high income inequality had the lowest rates of GAM. Since these countries are also among the richer countries in the sample, this further confirms that average income may be more important than income distribution in determining rates of malnutrition.
Chronic malnutrition has been studied extensively, though mainly through examining prevalence of stunting and underweight in populations. In this study, the proportion of the population with anaemia has been investigated. The mean prevalence of anaemia in this sample of countries is astounding, with more than 50% of children affected. This makes anaemia the most common form of malnutrition worldwide. Identifying the potential reasons for this enormous burden of anaemia should be of particular importance to policy makers especially as anaemia has been linked to impaired work capacity, loss of productivity and increased risk of mortality.
This study shows as expected that like GAM, anaemia is closely related to poverty. However, a strong contributing factor towards anaemia is gender inequality. In fact, gender inequality is the strongest single factor explaining anaemia prevalence. These findings demonstrate that whilst poverty reduction strategies seem effective in reducing acute malnutrition, anaemia on the other hand also requires a reduction in gender inequality and improvement of women's status in low- and middle-income countries. Governments of these countries should therefore strive to put gender equality at the centre of all policies and into their developmental agendas. Effectively targeting these health inequalities require dynamic action on their underlying causes.
Future studies using multilevel modeling may help provide further insights into the associations between these inequalities and malnutrition in developing countries, , while longitudinal studies will help ascertain causality.

References

Agee MD, 2010. Reducing Child Malnutrition in Nigeria: Combined Effects of Income Growth and Provision of Information about Mothers' Access to Health Care Services. *Social Science & Medicine,* 71(11):1973-1980.

Alderman H, Appleton S, Haddad L et al., 2001. Reducing Child Malnutrition: How far does Income Growth take us? *CREDIT Research Paper*, 1(5). Centre for Research in Economic Development and International Trade, University of Nottingham.

Armar-Klemesu M, Ruel M, Maxwell D et al., 2000. Poor Maternal Schooling is the Main Constraint to Good Child Care Practices in Accra. *Journal of Nutrition*, 130 (6):1597-1607.

Balarajan Y, Ramakrishnan U, Ozaltin E et al, 2011. Anaemia in Low-Income and Middle-Income Countries. *Lancet,* 378:2123-2135.

Bhalotra S & Rawlings SB, 2011.Intergenerational Persistence in Health in Developing Countries: The Penalty of Gender Inequality? *Journal of Public Economics,* 95:286-295.

Black RE, Allen LH, Bhutta ZA et al., 2008. Maternal and Child Undernutrition: Global and Regional Exposures and Health Consequences. *Lancet,* 371: 243–260.

Blakely T, Kennedy B, Glass R et al., 2000. What is the Lag Time between Income Inequality and Health Status? *Journal of Epidemiology and Community Health*, 54:318–319.

Blakely T, Lochner K, & Kawachi I, 2002. Metropolitan Area Income Inequality and Self-Rated Health. *Social Science & Medicine*, 54:65–77.

Boyle MH, Racine Y, Georgiades K et al, 2006. The Influence of Economic Development Level, Household Wealth and Maternal Education on Child Health in the Developing World. *Social Science & Medicine,* 63:2242-2254.

Bryce J, Boschi-Pinto C, Shibuya K et al., 2005. WHO Estimates of the Causes of Death in Children. *Lancet*, 365:1147–1152.
Bryce J, Coitinho D, Darnton-Hill I et al., 2008. Maternal and Child Undernutrition: Effective Action at National Level. *Lancet,* 371(9611):510-526.

Chambwera M, Mcgregor J & Baker A, 2011. *The Informal Economy: A Primer for Development Professionals on the Importance of the Informal*

Economy in developing Countries. London. International Institute for Environment and Development.

Deaton, A. and S. Zaidi, Guidelines for constructing consumption aggregates for welfare analysis. 2000, World Bank: Washington DC.

Deaton A, 2003. Health, Inequality, and Economic Development. *Journal of Economic Literature*, 41, 113-158.

de Benoist B, McLean E, Egll I et al., 2008. *Worldwide Prevalence of Anaemia 1993-2005: WHO Global Database on Anaemia. Geneva*. WHO. Available at http://whqlibdoc.who.int/publications/2008/9789241596657_eng.pdf . Accessed on 10/05/2013.

Demographic and Health Surveys, n.d. Available at http://www.statcompiler.com/ . Accessed on 05/08/2013.

Emanuel I, 1986. Maternal Health During Childhood and Later Reproductive Performance. *Annals of the New York Academy of Sciences*, 477: 27–39.

Engle P, Menon P & Haddad L, 1999. Care and Nutrition: Concepts and Measurement, *World Development*, 27:1309–1337.

Ezzati M, Lopez AD, Rodgers AA et al., 2004. *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors*. Geneva. World Health Organization.

Fernandez ID, Himes JH & de Onis M, 2002. Prevalence of nutritional wasting in populations: building explanatory models using secondary data. *Bulletin of the World Health Organization,* 80(4):282-291.

Filmer D & Pritchett LH, 1999. The Impact of Public Spending on Health: Does Money Matter? *Social Science and Medicine*, 49:1309–1323.

Gaye A, Klugman J, Kovacevic M, et al., 2010. Measuring Key Disparities in Human Development: The Gender Inequality Index. *Human Development Report Research Paper 2010/46*. New York. United Nations.

Hobcraft J, 2000. The Consequences of Female Empowerment for Child Well-being: A Review of Concepts, Issues and Evidence in a post-Cairo context. In (ed) *Women's Empowerment and Demographic Processes.* Pressner H and Sen G. Oxford. Oxford University Press.

Jejeebhoy SJ, 1995. *Women's Education, Autonomy and Reproductive Behaviour: Experience from Developing Countries*. Oxford. Clarendon Press.
Kalaivani K, 2009. Prevalence and Consequences of Anaemia in Pregnancy. *Indian J Med Res,* 130**:** 627–633.

Kakwani N, Wagstaff A & Doorslaer VE, 1997. Socioeconomic Inequalities in Health: Measurement, Computation and Statistical Inference. *Journal of Econometrics*, 77(1):87-104.

Kondo N, van Dam RM, Sembajwe G et al., 2012. Income Inequality and Health: The Role of Population Size, Inequality Threshold, Period Effects and Lag Effects. *J Epidemiol Community Health*, 66:1-6.

Larrea C, & Kawachi I, 2005. Does Economic Inequality Affect Child Malnutrition? The Case of Ecuador. *Social Science & Medicine*, 60:165–178.

Lerman RI, 1984. A Note on the Calculation and Interpretation of the Gini Index. *Economics Letters,* 15:363-368.

Leslie J, 1998. Women's Work and Child Nutrition in the Third World. *World Development* 16(11):1341-62.

Lynch, J, Smith, GD, Harper, S et al., 2004. Is Income Inequality a Determinant of Population Health? Part 1. A Systematic Review. *Milbank Quarterly*, 82:5-99.

McLean E, Cogswell M, Egli I et al., 2009. Worldwide Prevalence of Anaemia, WHO Vitamin and Mineral Nutrition Information System, 1993–2005. *Public Health Nutr,* 12**:** 444–54.

Menon P, 2012. Childhood Undernutrition in South Asia: Perspectives from the Field of Nutrition. *Economic Studies,* 58(2): 274-295.

Meinzen-Derr JK, Guerrero ML, Altaye M et al., 2006. Risk of Infant Anemia is Associated with Exclusive Breast-feeding and Maternal Anaemia in a Mexican cohort. *J Nutr,* 136**:** 452–58.

Monden CW & Smits J, 2009. Maternal Height and Child Mortality in 42 developing Countries.
Am J Hum Biol, 21(3):305-311.

Overseas Development Institute, 2010. The MDG fundamentals: Improving Equity for Development. *ODI Briefing Paper*. London. ODI.

Omar MM, Hogberg U & Bergstrom B, 1994. Fertility, Infertility and Child Survival of Somali Women. *Social Science & Medicine,*22(3):194-200.

Ozaltin, E, Hill K & Subramanian SV, 2010. Association of Maternal Stature with Offspring Mortality, Underweight, and Stunting in Low- to Middle-income Countries. *JAMA*, 303:1507–1516.

Pathak PK & Singh A, 2011. Trends in Malnutrition among Children in India: Growing Inequalities across Different Economic Groups. *Social Science and Medicine,* 73(4):576-585.

Pickett KE, Kelly S, Brunner E et al., 2005. Wider Income Gaps, Wider Waistbands? An Ecological Study of Obesity and Income Inequality. *J Epidemiol Community Health,* 59:670-674.

Pickett KE & Wilkinson RG, 2007. Child Wellbeing and Income Inequality in Rich Societies: Ecological Cross Sectional Study. *BMJ,* 335:1080.

Portman G, Hampshire K, Abane A et al., 2010. Where Dogs, Ghosts and Lions roam: learning from Mobile Ethnographies on the journey from school. *Children's Geographies,* 8(2):91-105.

Pritchett L & Summers LH, 1997. Wealthier is Healthier. *J Hum Resour,* 31:841–868.

Raj A, 2010. When the Mother is a Child: the Impact of Child Marriage on the Health and Human Rights of Girls. *Archives of Disease in Childhood,* 95:931–935.

Raj A, Saggurti N, Winter M, et al., 2010. The Effect of Maternal Child Marriage on Morbidity and Mortality of Children Under 5 in India: Cross Sectional Study of a Nationally Representative Sample. *BMJ*, 340(b4528):1-22.

Ram R, 2006. Further Examination of the Cross-Country Association between Income Inequality and Population Health. *Social Science & Medicine,* 62:779-791.

Ramalingaswami V, Jonsson U & Rhode J, 1996. The Asian Enigma, in UNICEF *The Progress of Nations.* New York: UNICEF.

Ref: Rosser JB, Rosser MV & Ahmed E, 2000. Income Inequality and the Informal Economy in Transition Economies. *Journal of Comparative Economics,* 28:156-171.

Sear R, Allal N & Mace R, 2004. Height, Marriage and Reproductive Success in Gambian Women. *Res Econ Anthropol,* 23:203–224.

Sen AK, 1999. Health in Development. *Bull World Health Organ,* 77:619–623.

Sen G and Batliwala S, 2000. Empowering Women for Reproductive Rights. In (ed) *Women's Empowerment and Demographic Processes.* Pressner H and Sen G. Oxford. Oxford University Press.

Shroff M, Griffiths P, Adair L et al., 2009. Maternal Autonomy is Inversely Related to Child Stunting in Andhra Pradesh, India. *Maternal & Child Nutrition*, 5:64-74.

Smith L & Haddad L, 2000. *Explaining Child Malnutrition in Developing Countries: A Cross-Country Analysis.* Research report 111. Washington D.C. International Food Policy Research Institute.

Smith LC & Haddad L, 2002. How Potent is Economic Growth in Reducing Undernutrition? What are the Pathways of Impact? New Cross-Country Evidence. *Econ Dev Cult Change,* 51: 55–76.

Smith LC, Ramakrishnan U, Ndaiye A et al., 2003. *The Importance of Women's Status for Child Nutrition in Developing Countries.* Research Report 131. Washington D.C. International Food Policy Research Institute.

Smith LC, Ruel MT & Ndaiye A, 2005. Why is Child Malnutrition lower in Urban than in Rural Areas? Evidence from 36 Developing Countries. *World Development,* 33(8):1285-1305.

Subramanian SV, Delgado I, Jadue L et al., 2003. Income Inequality and Health: Multilevel Analysis of Chilean Communities. *J Epidemiol Community Health*, 57:844-848.

Subramanian SV & Kawachi I, 2004. Income Inequality and Health: What Have We Learned so Far? *Epidemiologic Reviews,* 26:78-91.

Subramanian SV, Ackerson LK, Smith GD et al., 2009. Association of Maternal Height With Child Mortality, Anthropometric Failure, and Anemia in India. *JAMA,* 301(16):1691-1701.

Subramanyam MA, Kawachi I, Berkman LF et al., 2011. Is Economic Growth Associated with Reduction in Child Undernutrition in India? *PLoS Med* 8(3): e1000424. doi:10.1371/journal.pmed.1000424.

United Nations, 2000. *Millennium Declaration.* New York. United Nations.

United Nations Children's Fund, 2010. *Narrowing the Gaps to meet the Goals.* New York. UNICEF.

United Nations Children's Fund, United Nations University & World Health Organization, 2001. *Iron Deficiency Anaemia: Assessment*, *Prevention and Control*; *A Guide for Programme Managers*. Geneva. WHO. Available at http://www.who.int/nutrition/publications/en/ida_assessment_prevention_control.pdf . Accessed on 10/5/2013.

United Nations Children's Fund, World Health Organization & The World Bank, 2012. Levels and Trends in Child Malnutrition. *UNICEF-WHO-The World Bank Joint Child Malnutrition Estimates.* New York, UNICEF; Geneva, WHO; Washington D.C., The World Bank. Available at http://www.who.int/nutgrowthdb/jme_unicef_who_wb.pdf . Accessed on 10/5/2013.

United Nations Development Program, 1999. *Human Development Report* 1999. New York. United Nations.

United Nations Development Programme, 2013. The Rise of the South: Human Progress in a Diverse World. *Human Development Report 2013.* New York, UNDP. Available at http://www.undp.org/content/dam/undp/library/corporate/HDR/2013GlobalHDR/English/HDR2013%20Report%20English.pdf . Accessed on 10/05/2013.

United Nations High Commissioner for Refugees, 2011. *Dadaab Nutrition Survey Report, Aug-Sep 2011*. New York. UNHCR. Available at http://www.humanitarianresponse.info/system/files/documents/files/HelpAge%20Dadaab%20Nutrition%20Survey%202011.pdf . Accessed on 30/4/2013.

Upadhyay UD & Hindin MJ, 2005. Do Higher Status and more Autonomous Women have Longer Birth Intervals? Results from Cebu, Philippines. *Social Science & Medicine*, 60:2641–2655.

Van de Poel E, Hosseinpoor AR, Speybroeck N et al., 2008. Socioeconomic Inequality in Malnutrition in Developing Countries. *Bulletin of the World Health Organization,* 86:282–291.

Van Ourti T, van Doorslaer E & Koolman X, 2009. The Effect of Income Growth and Inequality on Health Inequality: Theory and Empirical Evidence from the European Panel. *Journal of Health Economics,* 28(3):525-539.

Varela-Silva MI, Azcorra H, Dickinson F, et al., 2009. Influence of Maternal Stature, Pregnancy Age, and Infant Birth Weight on Growth During Childhood in Yucatan, Mexico: A Test of the Intergenerational Effects Hypothesis. *Am J Hum Bio,* 21:657–63.

Wagstaff A & Wanatabe N, 2000. Socioeconomic Inequalities in Childhood Malnutrition in Developing World. *Policy Research Working Paper,* 2434. Washington D.C. World Bank.

Wagstaff A & Doorslaer EV, 2004. Overall versus Socioeconomic Health Inequality: A Measurement Framework and Two Empirical Illustrations. *Health Economics,* 13:297-301.

Warrell D, Cox T, Firth J et al., 2003. *Oxford Textbook of Medicine*. Oxford, UK: Oxford University Press.

Wells JCK, Marphatia AA, Cole TJ et al., 2012. Associations of Economic and Gender Inequality with Global Obesity Prevalence: Understanding the Female Excess. *Social Science and Medicine,* 75(3):482-490.

Weisstaub G, Araya M, Hill A et al. 2008. Childhood Malnutrition: Prevention and Control at the National Level. In Duggan C, Watkins JB &

Walker WA (Eds). *Nutrition in Paediatrics,* 4th Ed. Hamilton, Canada. BC Decker Inc. Chap 14:143-152.

Wilkinson, RG (1996). *Unhealthy Societies: the Affliction of Inequality*. London: Routledge.

Wilkinson RG, 2006. The Impact of Inequality. *Social Research*, 73(2):711-732.

Wilkinson RG, & Pickett KE, 2006. Income Inequality and Population Health: A Review and Explanation of the Evidence. *Social Science & Medicine*, 62, 1768–1784.

Wilkinson RG & Pickett KE, 2008. Income Inequality and Socioeconomic Gradients in Mortality. *American Journal of Public Health,* 98(4):699-704.

Wilson NW, Couper ID, De Vries E et al., 2009. A Critical Review of Interventions to redress the Inequitable Distribution of Healthcare Professionals to Rural and remote areas. *Rural and Remote Health,* 9(2):1060. Available at http://www.rrh.org.au/publishedarticles/article_print_1060.pdf . Accessed online on 01/08/2013.

World Bank, n.d. World Development Indicators. Available at http://www.worldbank.org . Accessed on 05/05/2013.

Zere E & McIntyre D, 2003. Inequities in Under-five Child Malnutrition in South Africa. *International Journal for Equity in Health,* 2:7.

Disclosure

All authors have seen and approved the abstract.

Past publication history

This study was developed as part of an MSc in Global Health and Development programme at the UCL Institute for Global Health, and as such has only been produced in a dissertation format, available upon request at UCL.

Past presentation history

If accepted, this will be the first presentation of the study results.

Founding sources

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Conflict disclosure

The authors declare no conflict of interest.

Appendix 1: Concentration Curve of distribution of Anaemia and GAM across countries, ranked by GDP/capita PPP

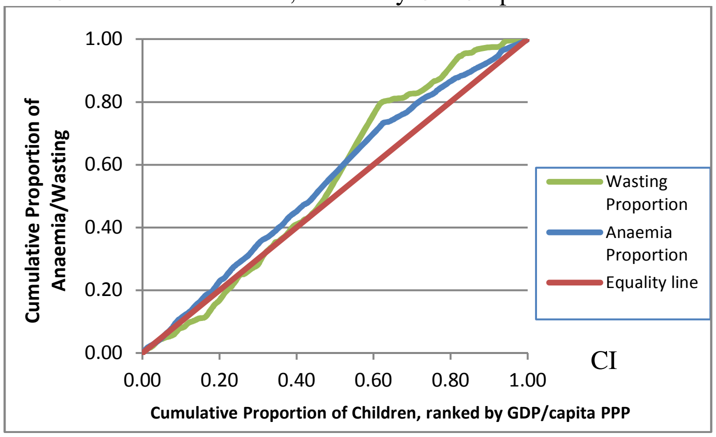

Figure 6: Concentration Curve for the distribution of anaemia and GAM across countries, ranked by the GDP/capita PPP, starting with lowest and ending at highest. CI Anaemia: Concentration Index for Anaemia Curve. CI Wasting: Concentration Index for Wasting Curve.

Appendix 2: Examples of distribution of variables and appropriate normality transformations.

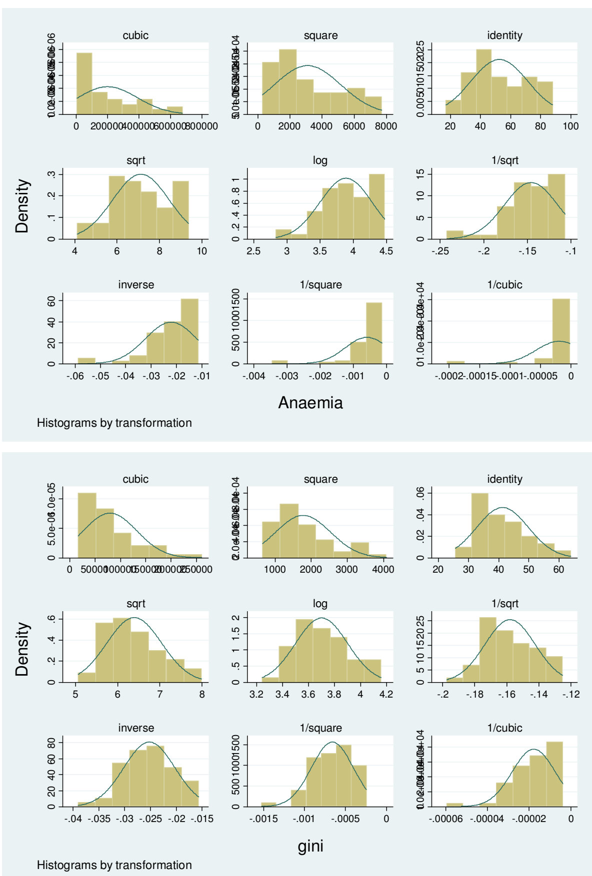

Figure 7: Histograms of anaemia and gini distribution and transformations. For anaemia, the original format (identity) gives the best normal fit, whilst that for gini is given by logarithm transformation

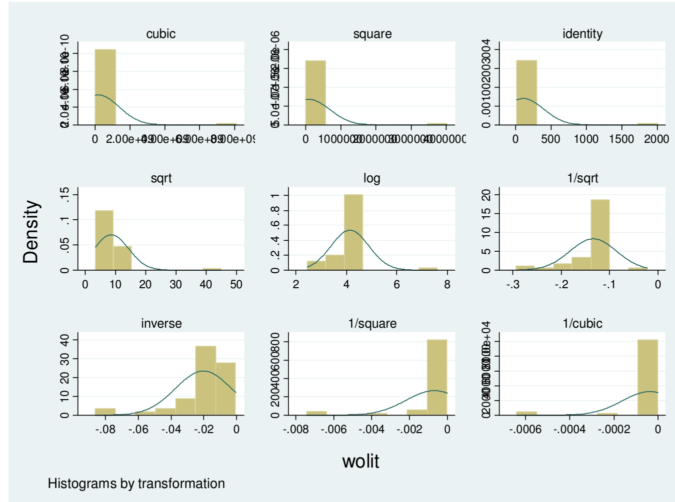

Figure 11: Histograms of Women's Literacy Rate (wolit) distribution and transformations. There is no best normal fit.

Appendix 3: Sensitivity Analysis with Concentration Curves

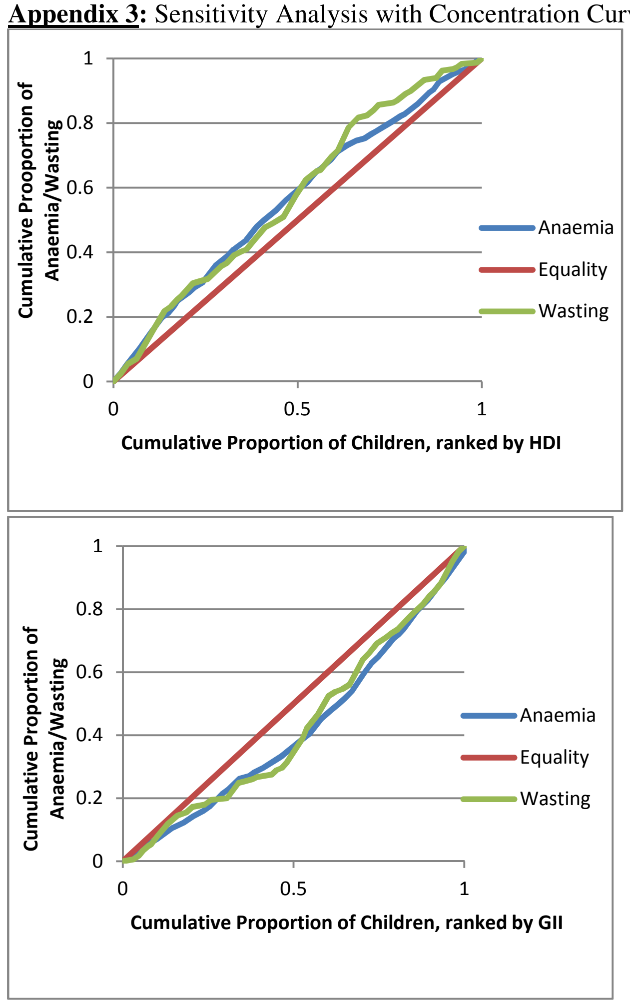

Figure 12: Concentration Curve for the distribution of anaemia and GAM across countries, ranked by the HDI and GII. 6 Countries with under-5s population > 100,000 have been excluded: Malawi, Nigeria, Indonesia, India, Dominican Republic and Columbia.