UNIVERSITY OF SOUTHAMPTON
FACULTY OF HUMAN AND SOCIAL SCIENCES
School of Social Sciences

Socio-Demographic Determinants of Anaemia and Nutritional Status in the Democratic Republic of Congo, Uganda and Malawi

BY

Ngianga II Kandala

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ABSTRACT

Anaemia is a worldwide public health concern. Anaemia is multifactorial and its related factors are classified according to their position in the pathophysiological process. Socioeconomic and demographic factors such as poor education, cultural norms such as food taboos can predispose children and women to anaemia through immediate causes such as physiological, biological, diet and infections. However, socioeconomic and demographic factors associated with anaemia are not widely reported and it is difficult to find published literature on this subject, which could be due to the lack of data. The objective of this research is to provide an understanding of socioeconomic and demographic factors related with anaemia among children and women and the links between anaemia during childhood and child nutritional status which can be used as a basis for policy formulation, planning and implementation.

Almost three quarters of children and half of women in DRC (2007), Uganda (2006) and Malawi (2004) are anaemic. Multilevel ordinal regression models were fitted for anaemia among children and multilevel logistic regression models for anaemia among women. The models showed variations in anaemia prevalence within the countries at the community level. However, country level interactions indicate that there are no significant differences in the risk of anaemia in children and women between these countries. Endogenous switching regression models were fitted to the data to explore the link between anaemia and child's health outcomes. Anaemia is endogenous to children's nutritional status (weight-for-age z-scores) which should be accounted for. The prevalence of anaemia is high in DRC (71%), Uganda (74%) and Malawi (73%) and anaemia is a severe public health problem in the three countries. Although it will take considerable time for the three countries to control anaemia, it is not an impossible task. By improving nutrition and iron status, and treating helminth and malaria infections, the prevalence of anaemia can decrease as observed in Malawi in 2010. More effort is needed to identify the pathways through which anaemia within each country may be addressed.

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Declaration of authorship

I, **Ngianga II Kandala**, declare that the thesis entitled

"**Socio-Demographic Determinants of Anaemia and Nutritional Status in the Democratic Republic of Congo, Uganda and Malawi**"

and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

this work was done wholly or mainly while in candidature for a research degree at this University;

- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
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- I have acknowledged all main sources of help;
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CHAPTER 1
Introduction

Anaemia is one of the most common health problems in both developed and developing countries. In developing countries estimates of the prevalence vary, but it is thought that between one and two-thirds of children are anaemic (Theodore and Varavikova 2008). Anaemia is one of the few nutritional disorders that affect a substantial section of the population. Recent estimates indicate that about 25% of the world population is anaemic, totalling about 2 billion people (Wagstaff, Bustreo et al. 2004; WHO 2008). Population groups that are at high risk of anaemia are pregnant women and children (Sastry, Suneela et al. 2004).

1.1.The problem statement and rationale for the study

Anaemia is of epidemiological importance and is among the leading causes of maternal and child mortality in developing countries (Brabin, Hakimi et al. 2001). The focus on anaemia in this study is important since it is the world's second largest cause of disability and death after malaria (Brabin, Premji et al. 2001). Anaemia is not only a major cause of pre and post-partum morbidities and mortalities for women in developing countries but it also affects the physical and cognitive development of children (Brant 1990; Sung-Yong, Nayga et al. 2001). Anaemia adversely affects the immune system and increases a person's susceptibility to infections (Li-qun and Qing-hua 1987; Ekiz, Agaoglu et al. 2005; Young and Kaufman 2008). Furthermore, anaemia affects a person's learning ability (Logan, Martins et al. 2001; Armstrong 2002). Work by Pollitt and others (1993) concluded that iron deficiency has adverse effects on cognition and the effects are most probably located at the level of information reception in the brain (Frewin, Henson et al. 1997; Dahl, Draptchinskaia et al. 1999; Ashok, Anuradha et al. 2004). In pre-school and school aged children, anaemia impairs motor development and administration, language development and scholastic achievement (Scrimshaw 1998; Lozoff, Jimenez et al. 2000). Some symptoms of anaemia in children may be psychological and behavioural effects such as inattention, fatigue and insecurity. Anaemia also decreases children's physical activity (DeMaeyer 1989). It is suggested that globally 200 million under-5 year olds fail to reach their cognitive and socioemotional development due to undernutrition and anaemia (Badham 2007).

The biological causes of anaemia are well documented (Moore 1999; Sarcletti, Bitterlich et al. 2002; Sullivan 2002). However, social, economic and demographic factors of anaemia-related factors are not widely reported due to the lack of appropriate data. This thesis contributions are (1) to provide an overview of socioeconomic and demographic factors related to anaemia in children and women and (2) to explore and clarify the link between anaemia and other children nutritional status. Demographic Health Surveys (DHS) from the Democratic Republic of Congo (DRC, 2007), Uganda (2006) and Malawi (2004) are used. The release of Malawi DHS for 2010 during the writing up of this thesis afforded the opportunity to study if the levels and determinants of anaemia among women have changed over times. The objective is to examine the prevalence and to provide an understanding of socioeconomic and demographic factors related to anaemia in children and women which can be used as a basis for policy formulation, planning and implementation.

There are limited anaemia preventive measures at the public health level in most developing countries even though it is one of the most prevalent public health problems, implicated in nearly a million deaths a year, and one of the leading cause of childhood mortality and morbidity (World Bank 2004). For this study, the choice of anaemia has been prompted by the fact that it is highly prevalent and of epidemiological importance in the Sub-Saharan African region. Socioeconomic factors associated with anaemia are not well documented. Nearly all of the intervention programmes for various health problems being carried out in the region lack well articulated research findings that can assist in efficient allocation of scarce healthcare resources (Nichter 1984; Jamison and Mosley 1991; Olusanya, Luxon et al. 2004).

More often, such programmes use poorly researched decisions or simply follow political dictates in the distribution of resources which creates a number of problems.

Accurate empirical evidence is essential for adequate disease control and prevention. Such actions can only be made if correct information reaches those in the position to take action. In the context of anaemia, this has been difficult to achieve partially because of a lack of data and proper analytical information on anaemia patterns. Without proper information that provides the right indicators, the fight against anaemia or other major diseases in the region can be difficult.

The motivation in choosing only three countries in Sub-Saharan Africa with representative data is because analysing all Sub-Saharan countries with anaemia data could have been a time consuming exercise. Another important reason for this study is that in DRC, there is not a single study yet that looks at the pattern of anaemia. A few studies, however, have looked at biological factors associated with anaemia in Malawi and Uganda with little emphasis on its socioeconomic-related factors, e.g. studies by Totin and colleagues and Calis and colleagues (Totin, Ndugwa et al. 2002; Calis, Phiri et al. 2008). Socioeconomic, behavioural and environmental factors related to anaemia have not been reported widely and it is difficult to find published literature on this subject. This lack of research on socioeconomic, behavioural and environmental factors related to anaemia may be due to two main factors:

(1) The lack of representative population based data. Few existing studies that are available use hospital based data to report prevalence rates among women and children attending hospital antenatal clinics.

(2) Because the aetiology of anaemia is complex and anaemia is multifactorial. For example, infection and malnutrition deficiencies coexists (Muniz-Junqueira and Queiróz 2002).

Different statistical models can be used in the analysis of the determinants of anaemia among children and women. Since anaemia can be measured using the haemoglobin levels, it is possible to treat anaemia as a continuous variable and therefore to apply ordinary least squares models as long as the regression assumptions hold. For the data used in this thesis, the linear regression assumptions did not apply as demonstrated in Section 3.3.1 and therefore we treated the response variable as categorical. Multilevel ordinal regression models are used for the analysis of anaemia among children in Chapter 4. These models account for the ordered nature of anaemia levels (no anaemia, mild, moderate and severe). From the review of the literature, the distinction between 'mild', 'moderate', and 'severe' anaemia in children is important since even mild anaemia can impair cognitive development of children. For this reason, four categories for anaemia are used to make the results comparable with those from the literature.

Logistic regression models are used to analyse anaemia among women in Chapters 6 and 7. Although the same can be said about distinguishing 'mild', 'moderate', and 'severe' anaemia in women, most studies use a dichotomous variable and hence binary logistic regression.

The use of multilevel models for the analysis of anaemia in women and children is warranted because the assumption of independent observations that is required in standard logistic regression cannot be supported with the data that we use in this thesis. Most DHS use cluster sampling, using communities such as villages or townships as clusters in the sampling process. These clusters can introduce lack of independence in the outcome variables because of unobserved, common influences such as shared beliefs concerning food, cultural practices, and use of health services (Kazembe, Appleton et al. 2007). Models that do not account for the survey design can underestimate the standard errors and overestimate the significance of some variables (van Duijn, van Busschbach et al. 1999).

The thesis also analyses and clarifies the links between anaemia and child nutritional status by taking into account unobservable factors (endogeneity). This is done in Chapter 5. Endogenous switching regression models are used to account for correlation between unobservable factors that might influence children's nutritional status and anaemia. Joint analysis of anaemia and child nutritional status can further correct for confounding or endogeneity bias, and thus, improve the internal validity of the study (Carter, Mendis et al. 2000).

1.2.Structure of the thesis and research questions

This thesis provides an overview of socioeconomic factors related to anaemia, with a focus on their coexistence at community and household levels, using appropriate approaches. The thesis also aims to provide a clear picture of social and environmental links between anaemia, and child nutritional status using simultaneous endogenous regression methods. There are in total 8 chapters in this thesis. The first chapter introduces the thesis followed by chapter two on the literature review which outlines the burden of anaemia together with the theoretical conceptual framework, definition, causes and a review of interventions for anaemia control and prevention. Chapter three describes the data used in this study and describes standard methods used, from specification of the statistical models to the interpretation of the results. Chapter four investigates the prevalence of anaemia and analyses risk factors associated with anaemia in children in DRC, Uganda and Malawi. In general, this chapter examines the prevalence of anaemia in children in DRC, Uganda and Malawi. It presents the individual, household and community risk factors associated with anaemia in children in these countries. This chapter also looks at whether the prevalence of anaemia varies between households and communities in the three countries. The chapter is able to answer the following research questions:

(a) What is the prevalence of anaemia in the selected countries?

(b) How does the prevalence of anaemia vary within and between the three countries?

(c) What are the individual, household and community risk factors associated with anaemia in children in these countries and how do they differ across the three countries?

Chapter five investigates the links between anaemia and child nutritional status. The aim of the chapter is to account for coexisting endogeneity caused by unobservable factors that affect both anaemia and the children's nutritional status. It also examines common socioeconomic and demographic risk factors associated with both anaemia and the overall nutritional status of children in these countries. Finally the chapter discusses possible unobserved factors that might affect both anaemia and child nutritional status, this chapter answers the following set of questions:

(a) Is anaemia endogenous to weight-for-age?

(b) What is the effect of ignoring endogeneity between anaemia and weight-for-age?

(c) What are possible common observed/unobserved factors that might influence anaemia during childhood and weight-for-age?

Base on the results from chapters four and five, which suggest that children of anaemic mothers are associated with an increased risk of anaemia and also with low mean weight-for-age, chapter six explores risk factors which are associated with anaemic in women. The chapter answers the following questions:

(a) What is the prevalence of anaemia among women in the selected countries?

(b) What are socioeconomic and demographic factors associated with anaemia among these women in each country?

(c) What are common risk factors of anaemia for both women and children?

Chapter seven provides a comprehensive review of the changes in the prevalence and risk factors of anaemia among women using Malawi Demographic and Health Surveys from 2010, which is the most recent survey. The review has not been possible for DRC and Uganda because there are no recently published data. In this chapter, the prevalence of anaemia in women in Malawi in 2004 and 2010 is described, compared between the two time periods. The chapter aims to examine whether there are changes in the prevalence of anaemia among women in Malawi and discusses various factors that might have brought about the changes. It answers the following research questions:

(a) What is the trend in the prevalence of anaemia among women in Malawi and how does it differ by the selected characteristics over time?

(b) What factors can be identified as contributing to changes in anaemia level amongst women in Malawi between 2004 and 2010?

Lastly, Chapter 8 summarises all the findings and discusses the general picture of the results and makes recommendations that are focused on improving the control and preventive strategies against anaemia. The recommendations are focused on control, preventive strategies against anaemia in women and children and other major diseases and further research to examine factors that were not captured by this thesis. These will include more nutritional education to improve dietary intakes and targeted interventions to communities that need help most.

CHAPTER 2
Literature Review

2.1. Introduction

This chapter discusses anaemia, a worldwide health problem. This chapter reviews work by epidemiologists and other scholars that highlight this public health problem and factors associated with child or maternal health. It provides in-depth information and facts that emphasise the magnitude, implications, prevalence and preventive methods which have been successful in reducing anaemia in other parts of the world. Anaemia has affected a large segment of the world's population. Anaemia, like many other health issues affecting children and women in developing countries, is influenced by diverse factors (Wagstaff, Bustreo et al. 2004; Badham 2007; Bryg 2008). It is the aim of this chapter to review the literature in order to understand what these factors are, and the health and economic consequences associated with anaemia at the household and community levels for both women and their children.

The chapter is divided into six further sections. The first section defines and describes the concepts of anaemia, haemoglobin, and altitude measures. The second section describes the methodology for the literature review, and the third presents the prevalence and magnitude of anaemia, describing the impact of anaemia on social and economic development. Section four presents the causes of anaemia. Section five presents and explains the theoretical conceptual framework used in this study. Finally, section six discusses preventive methods that have been shown to be effective and section seven contains a summary.

2.2. Definition of key concepts used in this study

This section defines the concepts used in this study. Anaemia is a condition which occurs when the body has an abnormally low amount of red blood cells (DeMaeyer 1990). Clinical studies show that red blood cells contain haemoglobin, a red pigment which gives blood its colour (Brabin, Premji et al. 2001). Haemoglobin carries oxygen around the whole body's tissues in sufficient amounts. When the amount of red blood cells and therefore haemoglobin is reduced, the blood fails to supply the body's tissues with the required amount of oxygen (WHO 2000). As a result, the lungs and heart will then have to work harder to get oxygen into the blood, resulting in difficulties in breathing (Singh, Szczech et al. 2006). The haemoglobin level is measured as gram per decilitre (g/dl) or in gram per litre (g/l). The definitions of anaemia and its prevalence differ between studies. However, most studies use conventional cut-off points defined by the World Health Organisation (WHO 2001), as shown in Table 2.1.

Table 2.1. Haemoglobin cut-off points for anaemia

Population group	Haemoglobin concentration in g/dl
Children aged 6 months to 59 months	≤11.0
Children aged 5 to 11 years	≤11.5
Children aged 12 to 14 years	≤12.0
Adult males	≤13.0
Adult female, non-pregnant	≤12.0
Adult female, pregnant	≤11.0

Source: WHO (2001)

Table 2.1 indicates haemoglobin values below which anaemia could be considered to exist for each population group. For both adults and children, anaemia is classified as mild if the haemoglobin concentration level is between 10-11.9 g/dl, moderate if the level is between 7-9.9 g/dl and severe if the haemoglobin level is below 7g/dl (Radi, Mourad et al. 2009).

Before 2000, haemoglobin concentration was only measured by laboratory-based haemoglobinometry in hospitals (WHO 2000). This can partially explain the historical lack of representative data on anaemia. However, with advances in technology, simple, reliable, cheap and effective medical devices for the diagnosis of anaemia levels are available (Zijlstra 2007). These devices are uniquely designed for rapid field surveys, where blood collection and haemoglobin determination do not require addition of any reagent and even survey staff without specialised laboratory training can successfully use the devices. These include Colorimeter, Haemoglobin Colour Scale, the Cyanmethemoglobin method and HemoCue (WHO 2000). The cyanmethemoglobin remains the best laboratory method of measuring haemoglobin concentration and is mostly used as a reference method for comparison and standardisation of other methods (Jeremiah, Uko et al. 2007). The HemoCue is a portable, battery-operated photometer with which blood is collected and it is uniquely suited to rapid field surveys. It has accurate and precise results when compared to laboratory methods (WHO, 2000).

The haemoglobin level may vary because of a person's biological constitution and the surrounding environment conditions such as the altitude, alongside socioeconomic and demographic factors. The altitude in which the area is located determines the partial pressure of oxygen in that specific geographical area, and humans living at altitude experience hypoxia and develop several physiological adaptations (Blumberg, Keller et al. 1973; Akhwale, Lum et al. 2004). Higher concentration of haemoglobin in the blood is one among many other physiological adaptations for individuals living at higher altitude, for example on a mountain (Gibson 2005; Van Patot and Gassmann 2011). For this reason, haemoglobin measures should always be adjusted by altitude. Based on the international criteria on altitude ranges defined by the World Health Organisation and the UNICEF (see Table 2.2) the adjustment is subtracted from each individual's observed haemoglobin level to calculate adjusted haemoglobin. For example, for an individual living in an altitude between 1,000 m and 1,250 m, the adjustment is made by subtracting 0.2 g/dl from the observed haemoglobin level before making any comparison with the cut-off points shown in Table 2.1. No adjustment is made in the haemoglobin level for individuals living in an altitude below 1,000 meters (Sullivan, Mei et al. 2008).

Table 2.2: Haemoglobin adjustment for altitude

Altitude range (m)	Haemoglobin adjustment (g/dl)
m < 1000	No adjustment
1000≤ m <1250	-0.2
1250≤ m <1750	-0.5
1750≤ m <2250	-0.8
2250≤ m <2750	-1.3
2750≤ m <3250	-1.9
3250≤ m <3750	-2.7
3750≤ m <4250	-3.5
4250≤ m <4750	-4.5
4750≤ m <5250	-5.5
5250≤ m	-6.7

Source: Sylvain, Mei et al.(2008)

2.3. Literature search methodology

2.3.1. Search methods

Published studies on the relationship between anaemia and its related factors were searched for in a number of databases and journals. Databases included PubMed Central, POPLINE, Medline and JSTOR. Also Google scholar was used. Journals such as Paediatrics (Official Journal of the American Academy of Paediatrics), American Journal of Clinical Nutrition, and Science Direct (ELSEVIER), American Journal of Nutrition were also used. Different combinations of words and phrases were entered in the search as key words and are listed in Appendix 2.1. Manual searches of references cited were also conducted. The search focused mainly on socioeconomic and demographic determinants of anaemia in children and women in developing countries. The keywords used for the literature search were divided into 3 groups (A, B and C), where A included keywords relating to anaemia, B for keywords relating to socioeconomic and demographic determinants of anaemia, whether among children or women, and C for other keywords such as anaemia/anemia (American spelling), socioeconomic factors and anaemia (see Appendix 2.2). Combinations such as A&B, A&B&C, A&C or B&C were also used. In total, about 400 papers were found and of these, only 316 papers on anaemia in children and women were included in the literature and are listed in the bibliography.

2.3.2. Selection of references

Most studies regarding anaemia focus on the biological determinants. As this thesis studies anaemia in children and women, the selection of studies for inclusion in the literature was based on whether they were about anaemia among these groups. The selected papers were used to identify further literature relating to anaemia and its socioeconomic and demographic characteristics where possible. The studies screened include cross-sectional studies, randomised controlled trials, longitudinal studies, systematic reviews and case-control study. Key studies are listed in Appendix 2.1.

2.4. The prevalence and consequences of anaemia

Recent estimates indicate that about 25% of the world population is anaemic, totalling about 2 billion people (WHO 2008). However, available prevalence data indicates that 90% of the anaemic population may be found in developing countries where two groups of the population: infants and pre-school children; and women of reproductive age as the most vulnerable (WHO 1996).

Over half of the population in most developing countries are affected by iron-deficiency anaemia (Cook 2005). The World Health Organisation estimated that 35% to 75% (56% on average) of pregnant women in developing countries and 18% of those in developed countries are anaemic (Allen 2000).

Globally 47.4% of preschool aged children and 30.2% of non-pregnant women are anaemic (Badham, 2007). The highest prevalence both groups is in Africa, but the greatest number is in Asia (Benoist, McLean et al. 2008). This suggests that half of the world's population of preschool aged children and pregnant women reside in countries where anaemia is a public health problem (see Table 2. 3).

Table 2.3. Global anaemia prevalence and number of individuals affected.

	Prevalence		Population affected	
Population group	Percentage	95 % CI	Number(millions)	95 % CI
Preschool-age children	47.4	45.7-49.1	293	283-303
School-age children	25.4	19.9-30.9	305	238-371
Pregnant women	41.8	39.9-43.8	56	54-59
Non-pregnant women	30.2	28.7-31.6	468	446-491
Men	12.7	8.6-16.9	260	175-345
Elderly	23.9	18.3-29.4	164	126-202
Total population	**24.8**	**22.9-26.7**	**1620**	**1500-1740**

Source: Benoist, McLean et al. (2008), Global database on anaemia.

Compared to North America, anaemia is three times more prevalent in Europe and this may be because countries with a range of social and economic profiles are included or because data coverage is lower in Europe than in North America (Badham 2007). The number of individuals affected by anaemia is increasing. Previous estimations from 2004 (WHO 2004) indicated that globally 1.62 billion people (95 % CI: 1.50 -1.74 billion) worldwide were anaemic (see Table 2.3).

The figures in Tables 2.3 were estimated using administrative and population survey data collected between 1993-2005 from the WHO 192 member states. Administrative survey and population surveys information were used. In most of the countries, the most recent national survey was used where available. For countries in conflict where a region is left out because of security reasons, available data from the missing region within the time frame were used and weights were applied in order to obtain national estimates for the country. Since local and district level surveys are more likely to be biased, they were not included. For countries without survey data, multiple regression models and the 2002 United Nations Human Development Index that includes health indicators from the World Health Statistics Database were used to predict the prevalence of anaemia in such countries for each age group. The global (world) prevalence of anaemia for each age group was computed by summing the number of individuals affected for each country divided by the total population (projections from the 2004 revision of the United Nation's population estimates) in that age group (Benoist, McLean et al. 2008). Some of these figures might not be very good but are used because of the lack of accurate information.

For each country, estimates based on survey data or regression based estimates were combined to get an aggregated (country) level estimate for each age group; see Tables 2.3 & 2.4. The results suggest that among all the age groups, preschool aged children, pregnant and non-pregnant women, Africa has the highest prevalence of anaemia followed by South Asia and Eastern Mediterranean for preschool children and for pregnant women. Similar results are suggested in the studies byYip and Ramakrishnan (2002); Awasthi and Bundy (2007); Tolentino and Friedman (2007); Xing, Yan et al. (2009). However, the prevalence of anaemia is lower in Europe, America and the Western Pacific (see Table 2.4).

Table 2.4: The prevalence of anaemia by WHO region

Who region	Preschool-age children[1]		Pregnant women		Non-pregnant women	
	Prevalence (%)	Affected (millions)	Prevalence (%)	Affected (millions)	Prevalence (%)	Affected (millions)
Africa	67.6	83.5	57.1	17.2	47.5	69.9
Americas	29.3	23.1	24.1	3.9	17.8	39.0
South-East Asia	65.5	115.3	48.2	18.1	45.7	182.0
Europe	21.7	11.1	25.1	2.6	19.0	40.8
Eastern Mediterranean	46.7	0.8	44.2	7.1	32.4	39.8
Western Pacific	23.1	27.4	30.7	7.6	21.5	97.0
Global	47.4	293.1	41.8	56.4	30.2	468.4

Source: Benoist, McLean et al. (2008); 1=children aged between 0-4.99 years

Anaemia is categorised as follows: if the prevalence of anaemia is <5% it is a low public health problem, from 15 to 19.5%, mild public health problem, from 30 to 39.9% it is a moderate public health problem and ≥40% it is a severe public health problem (WHO, 2008). Furthermore, in over 80% of the world's countries there is a moderate or a severe problem of anaemia in preschool-age children and pregnant women (see Table 2.5). Recent estimates indicate that the number of affected people has increased from 1.6 billion in 2005 to about 2 billion people worldwide in 2008 (WHO, 2008).

Table 2.5: Number of countries by public health significance of anaemia.

Public health concern	Preschool-age children Number of countries	Pregnant women Number of countries	Non-pregnant women Number of countries
Low	2	0	1
Mild	40	33	59
Moderate	81	91	78
Severe	69	68	54

Source: (Benoist, McLean et al. 2008), Global database on anaemia.

2.4.1. The impact of anaemia on health

Anaemia is a major public health problem especially among poorer population groups in developing countries. Anaemia has many negative effects ranging from personal health and self-fulfilment to national socioeconomic development. Children under 5 years, pregnant and non-pregnant women are among vulnerable groups. In this section the impact of anaemia on health is documented for children, adults and pregnant women.

Impact of anaemia in children

Anaemia is often associated with childhood malnutrition, impairment of red cell production and increased red cell destruction, which could increase mortality risk (Brabin, Premji et al. 2001). Representative data on childhood mortality attributable to anaemia are scarce. The estimated childhood death attributable to anaemia reported in Table 2.6 is a summary of hospital and non-hospital setting data from the Global Burden of Disease as cited in Brabin and colleagues (Brabin, Premji et al. 2001). Hospital data might not be representative or have selection bias because not everyone can afford and attend hospital in poor regions of the world. These data are reported because of the lack of information on anaemia-related deaths and need to be interpreted with caution. Anaemia-related deaths remain higher in less developed countries and it is known to differ by region, sex and age (Schellenberg et.al., 2001a*)*. Asia has the highest number of child anaemia-related deaths for both sexes followed by Sub-Saharan Africa (Brabin, Premji et al. 2001). The number of deaths due to anaemia is highest among males aged between 0-4 years and females between the ages of 5-14 years as presented in Table 2.6. These results are estimated mostly based on hospital data and need to be interpreted with caution for the following two reasons (1) due to the lack of representativeness and (2) due to selection bias (not everyone attend hospital in developing countries).

Table 2.6. Estimated anaemia deaths (in thousands) in children in 2001

	Males		Females	
Region	0-4 y	5-14 y	0-4 y	5-14 y
Less developed (all)	19.9	6.0	16.2	23.0
India	6.4	1.3	5.3	7.2
China	1.5	-	4.8	2.3
Other Asian and Islands	2.9	1.2	1.4	4.6
Sub-Saharan Africa	4.3	1.1	1.9	4.9
Latin America and Caribbean	1.5	-	1.1	-
Middle East	3.3	-	1.8	3.3
World	20.1	6.2	16.4	23.2

– means that data were not available.
Source : Schellenberg et.al., 2001a.

Several studies have established that anaemia affects a person’s learning ability (Walter, Kovalskys et al. 1983; Lozoff 1989; Kosen, Herman et al. 1998). Iron deficiency anaemia has adverse effects on cognitive performance and physical growth of infants, preschool and school aged children. Some of these effects may not be reversible even following intervention to increase haemoglobin levels (Otta 1992).

Experimental studies based on animals suggest that iron plays a major role in brain functions. Randomised controlled trials were conducted to assess the effect of iron deficiency on children’s cognition in Chile, Costa Rica, Guatemala and Indonesia. Children with normal iron nutrition were used as control group. Iron deficiency was conclusively identified to delay psychomotor development and impair cognitive performance of infants in Chile (Walter, Kovalskys et al. 1983), Costa Rica (Lozoff 1989; Lozoff, Jimenez et al. 1991; Lozoff, Wolf et al. 1996), Guatemala (Pollitt 2000) and Indonesia (Kosen, Herman et al. 1998), in pre-school and school aged children in Egypt (Lozoff, Jimenez et al. 1991), India (Seshadri and Gopaldas 1989), Indonesia (Soemantri, Pollitt et al. 1985; Soemantri 1989), Thailand (Victora, Huttly et al. 1992) and USA (Halterman, Kaczorowski et al. 2001; Taylor 2002). Anaemia impairs the motor development and administration, language development and educational achievement of children (Paxson and Schady 2007).

In Costa Rica, it was found that compared with children who were not anaemic during infancy those who had moderate anaemia as infants had lower scores on intelligence tests (IQ) and other cognitive performances. These results were consistent even after controlling for other socioeconomic factors (Lozoff, Jimenez et al. 1991). Similar results were found in Chile (Walter 1994) and Thailand (Victora, Huttly et al. 1992; Walter 1994).

Another study that reviewed 26 randomised clinical trials on the prevention of iron deficiency anaemia in children in developing countries found similar results to the one found by Walter suggesting that iron deficiency can also impair cognitive performance at any stage of life (Iannotti, Tielsch et al. 2006). Surprisingly, even mild anaemia can impair intellectual development of children. The effects of iron deficiency during infancy and early childhood may not be completely corrected by iron supplements (Pollitt, Hathiral et al. 1989). There is also some evidence that anaemia is associated with lower weight gains among infants and children (Burman 1982; Kumar Chandra 1983). Anaemia also increases the risk of contracting infections, which may be due to lowered concentration of cells responsible for cell-mediate immunity.

Impact of anaemia in adults

Although some study findings suggest that children with chronic severe anaemia have lower chances of surviving until adulthood, the degree to which anaemia during childhood can be linked to adulthood life is yet to be explored (Booth and Aukett 1997; Blom, Buikstra et al. 2005). Lower oxygen transport in the body, due to anaemia has been argued to reduce work productivity (Li, Chen et al. 1994; Haas and Brownlie 2001; Horton and Levin 2001; Aburto, Ramirez-Zea et al. 2009). In adults of both sexes, anaemia decreases physical capability, earning capacity and resistance to fatigue (Stoltzfus, Ayoya et al. 2006).

Iron deficiency anaemia affected the work capacity for agriculture workers in Indonesia (Kosen, Herman et al. 1998) and Nepal (Panter-Brick, Miller et al. 1992) and the work capacity returned rapidly to normal with iron supplementation.
In China, anaemic female workers were 15% less efficient in performing their work compared with those who were not anaemic (Li, Chen et al. 1994). Iron deficiency anaemia may adversely also affect the immune system (Sherman and Peter 1998) which may increase a person’s susceptibility to infection (Stoltzfus, Ayoya et al. 2006; Jans, Daemers et al. 2009).

Impact of anaemia in pregnant women

Anaemia during pregnancy has serious clinical consequences. During pregnancy the foetus and placenta need an increased iron supply, which can be obtained only from the mother (Xing, Yan et al. 2009). For this reason, pregnant women need more iron than before they were pregnant and women often become anaemic as the demand for iron and other vitamins is increased during pregnancy (Allen 2000). When the haemoglobin concentration falls below 4.1g/dl, most of the body tissues become starved of oxygen and the heart muscles are likely to fail, resulting in death (Jamison and Mosley 1991; Clegg and Weatherall 1999). Severely anaemic pregnant women are less able to withstand blood loss and may require a blood transfusion, which is not always available in poor countries and, where available, is not without risk (Scholl and Hediger 1994). Heart failure and shocks due to anaemia can be a contributory cause of maternal deaths (Clegg and Weatherall 1999). For example, a study conducted in two refugee camps in Somalia found that anaemia was the primary cause of maternal death and of the 44 deaths recorded, 42 had causes related to anaemia (Clegg and Weatherall 1999). Using community based estimates, similar results were found by Abouzahr (1991), suggesting that in most countries with high maternal mortality, anaemia is cited as the primary or the secondary cause. Where anaemia is not the primary cause of death it contributes indirectly through other causes. Using community based studies, Brabin et al. (2001a) found that in Kenya anaemia was responsible for 82 deaths per 100,000 live births (11 % of the total number of deaths) and 194 deaths per 100,000 live births in Pakistan, 47% (see Table 2.7).

Table 2.7. Maternal mortality attributed to anaemia in selected countries in 1993

Country	Anaemia related deaths per 100000 live births [1]	Estimated total number of deaths (95% C.I) [2]	% of deaths attributable to anaemia[3]
Kenya	82	730 (437-1157)	11
Malawi	48	1662 (1034-2551)	3
Nigeria	34	694 (435-1041)	5
Senegal	35	491 (306-765)	7
Bangladesh	54	574 (344-900)	9
Bhutan	55	481 (186-1063)	11
India	37	318 (190-506)	12
Pakistan	194	415 (235-679)	47

1. Source : (Brabin, Hakimi et al. 2001), community based data
2. Source:(Hogan, Foreman et al. 2010), estimated based on data from the Global Burden of Diseases (2001)
3. Percentages of maternal mortality attributable to anaemia

In 1995, researchers from WHO, in a study reviewing the symptoms associated with maternal deaths, found that in Tangail, Bangladesh, anaemia was the secondary cause of deaths in every case, and in Malawi (Kamuzu Hospital, Lilongwe) anaemia was responsible for 23% of deaths (WHO, 2001a). Anaemia in child bearing women is associated with an increased maternal mortality especially from haemorrhage (Rush 2000), prenatal and perinatal deaths. Other studies of anaemia during pregnancy (Pollitt 1982; UNICEF 2004; Stoltzfus, Ayoya et al. 2006; Xing, Yan et al. 2009) have established a connection between anaemia and unfavourable pregnancy outcomes such as increased risk of foetal morbidity and mortality, premature birth, low birth weight, and prenatal mortality (Tolentino and Friedman 2007).

Economic implications of anaemia

Anaemia has serious economic consequences for national development. Although national estimates on the economic consequences due to anaemia are not provided it is estimated that total attributed global burden of anaemia amounts to 841,000 deaths and 35,057,000 disability adjusted life years (DALYs) (WHO, 2008). Other economic implications of anaemia include increased maternal mortality that may reduce general productivity, and increased long-term negative consequences of impaired mental development of children and premature deaths of young mothers. Low-income generating capacity among anaemic workers, higher level of undernutrition and the costs related to the interventions for nutrition and health education are among many other true handicaps imposed by anaemia on society (Bryce, Coitinho et al. 2008). These consequences can affect not only individuals but also family and communities, as well as the overall socioeconomic development of societies.

Other economic implications of anaemia include private and non-private medical cost associated with anaemia as well as some measure of income that is foregone as a result of anaemia and its related causes (Phadtare, Vinod et al. 2004). They include such factors as doctor’s fees, the cost of iron supplement and the cost of transportation to medical facilities and the necessary support provided to treat anaemia or its related causes such as malaria. Non-private costs include public expenditures on both prevention and treatment of anaemia (e.g iron supplementation to all women attending antenatal clinics).

2.5. Causes and types of anaemia

There are many possible types of anaemia and each one has different causes. However, many studies have grouped them into the following three broad categories (1) anaemia due to poor diet (generally known as nutritional anaemia) (2) anaemia caused by biological abnormalities (e.g. hereditary conditions) and (3) anaemia associated with infections (Heckman 1979). This section will discuss the main factors related to each of these three different types.

2.5.1. Causes of nutritional anaemia

Nutritional anaemia is the most prevalent type of anaemia throughout the world. It is mainly caused by micronutrient deficiencies such as iron, vitamin A, vitamin B_{12}, or folic acid. Iron, Vitamin A, Vitamin B_{12} and folic acid are needed in the body in order to produce red blood cells, so if one or more of these are deficiently lower, then anaemia may develop.

Iron deficiency is the most common form of malnutrition in the world (WHO 2001). By definition, iron deficiency is the result of long-term negative iron balance and it is important since most of the human tissues need iron in order to function properly. Iron deficiency (iron deficiency without anaemia) occurs when iron stores in the form of heamosiderin and ferritin are progressively diminished and no longer meet the needs of normal iron turnover (WHO, UNICEF et al. 2001; Gibson 2005). When the supply of iron to transport protein apotransferrin becomes compromised this results in a decrease in transferrin saturation and an increase in transferrin receptors in the circulation and on the surface of cells. The compromised supply of iron to the erythron is directly linked with a similar insufficient supply of iron to all other tissues in the human body (Ullrich et al. 2005). Low iron store causes a detectable change in classical laboratory tests including measurement of haemoglobin, transferrin saturation, and total iron-binding capacity but the tests are not limited to these. When iron is deficient, haemoglobin concentration is reduced to below-optimal levels and hence iron deficiency anaemia (Lin, Lin et al. 2010). Low haemoglobin concentration is the extreme end of iron deficiency and develops after a gradual process of iron depletion. For instance, there will be many individuals with iron deficiency (without anaemia) in addition to those with iron deficiency anaemia. There are several measures of iron nutritional status and haemoglobin measure is the simplest to measure under field conditions. However, it can only detect latest stages of iron deficiency (Gibson 2005).

The link between iron deficiency and infectious diseases is explained through the adverse effect of iron deficiency on the immune system (Walter, Arredondo et al. 1986). With iron deficiency, leukocytes have a reduced capacity to destroy ingested microorganisms and the lymphocytes have a decreased ability to replicate when stimulated by a mitogen. With iron deficiency the cell-mediated immunity concentration become lower, the skin test responsible to common antigens is depressed. Hence, the individual then become exposed to infectious diseases (von Ruecker 2003; Emadi, Jahanshiri et al. 2011). Iron forms part of the molecule haemoglobin, which is in red blood cells. Iron absorbed from diet is delivered to the bone marrow where red blood cells are formed. Any excess iron is stored either in the bone marrow or in the liver or spleen. A normal human body contains about 2g to 4g of iron (Belitz, Grosch et al. 2009).

The prevalence of anaemia is higher in less-developed countries and lower in developed regions (Dreyfuss and Stoltzfus 2002). Iron deficiency anaemia is most prevalent and severe in young children (6-24 months) and women of reproductive age (Dreyfuss and Stoltzfus 2002). The main reason why women of the reproductive age may have a shortage of iron is because of a poor diet (diet low in micronutrients such as Vitamin A and iron), exacerbated by heavy menstrual periods.

Vitamin B_{12} deficiency anaemia (also called pernicious anaemia) is mostly caused by inadequate absorption of Vitamin B_{12} from the diet. This can be due to ulcers, stomach cancer, diseases or after effects of surgery (Murray and Lopez 1997). Folic acid deficiency is due to a poor diet and also if a person drinks excessive alcohol the uptake of folic acid can be reduced. Folic acid can be found in fresh fruit, raw green vegetables, beans and whole grain cereals.

Child nutritional status such as weight-for-age and height-for-age has also been found to be strongly related with nutritional anaemia. For example a study by Georges and Kumar et.al (2000) using hospital based data from Kerala (India) attempted to study the relationships between anaemia and child nutritional status such as weight-for-age and height-for-age. Simple logistic regression models were used with anaemia as a binary outcome, weight-for-age and height-for-age z-cores alongside demographic characteristics as predictors. The study concluded that there is strong correlation between anaemia and other nutritional status such as underweight (weight-for-age) and height-for-age. Another study by Awasthi et al. found similar results suggesting a strong positive association between child nutritional status and low haemoglobin levels (Awasthi, Das et al. 2003).

These studies suggest that underweight and stunted children are associated with an increased risk of low mean haemoglobin levels, anaemia. The results from these two studies need to be interpreted with caution for the following reasons:

- Anaemia and other nutritional status are known to be results of undernutrition. Thus, anaemia might be strongly correlated with other child nutritional status (e.g. weight-for-age and height-for-age). In addition, it is difficult to tell whether it is because children are underweight (have weight-for-age below the recommended cut-off point for the reference population) that they are likely to become anaemic or because of anaemia that they are underweight. It is difficult to tell which should be used as predictor or as the outcome. Using one to predict the other without accounting for the existing correlation could yield biased estimates.

- Both studies use hospital based data which are not representative sample of a general population of pre-school children. Thus uncertainty exists regarding the generalizability of these results and their current value for making epidemiological associations between anaemia and other nutritional status. The results using representative sample might yield different conclusions. Therefore, further studies using a representative data and appropriate methods are needed in order to understand the link between children's nutritional status and anaemia.

The relationship between anaemia and child nutritional status, in the thesis is examined using anaemia and weight-for-age-z-scores. Weight-for-age is used instead of height-for-age or weight-for-height because weight-for-age can measure both long-term and short-terms undernutrition (McDowell and King 1982). Malnutrition can occur as a consequence of chronic undernutrition or from acute, short-term malnutrition. Hence using weight-for-age is better since it captures both forms of malnutrition.

Seasonal variation in rural areas in less developed countries might be amongst many other factors of iron deficiency anaemia. In less developed countries, most people make their living directly from the lands. However, there are commonly wide variations in seasonal food availability. It is argued that 'people tend to eat more when food is readily available' (Simondon, Benefice et al. 1993). However, in those regions where there is one main staple crop a year (e.g rice rich in iron, tubers which produce green leafy vegetables) nutritional status including anaemia may vary throughout the year (Simondon, Benefice et al. 1993). This can have a significant effect on health and particularly on the prevalence of iron deficiency anaemia. Seasonal food variations might increase or decrease the prevalence of iron deficiency anaemia thought these in different ways (Zimmermann, Chaouki et al. 2005). For example, green leafy vegetable can become rare during dry seasons and abundant during the rainy seasons (Hatibu, Mutabazi et al. 2006; Poulton, Kydd et al. 2006).

2.5.2. Biological causes of anaemia

Biological (genetic) factors cause anaemia in different ways. These include conditions such as changes in sickle cells traits which are the main causes of sickle cell anaemia, thalassemia, abnormal breakdown of red blood cells in the blood vessels and other causes of fanconi anaemia (Whitney, Saito et al. 1993). Most of the genetic conditions that cause anaemia are inherited from parents. For example, sickle-cell anaemia is a genetic condition, which is an inherited blood disease from parents to children (WHO 2006). In 2006, the WHO reported that the number of people worldwide with sickle-cell genes amounted to 5% and about 300,000 new born children were found with this genetic disorder each year. Africa alone had 200,000 cases (WHO 2006). Sickle-cell anaemia is not only common in developing countries, but increasingly in developed countries. In America, for example, the WHO (2006) suggested that sickle-cell anaemia is prevalent and that it is higher among African-Americans than it is among other ethnic groups.

Haemoglobinopathies are argued to be the commonest genetic diseases throughout the world with about 5% of the world population carriers of one or more forms of thalassemia and other structural variants of haemoglobin (Clegg and Weatherall 1999). Thalassemia and iron deficiency anaemia can have similar symptoms. Microcytosis is another rare form of genetic condition associated with iron overload of body tissues (Demir, Yarali et al. 2002). The biological causes of anaemia are well documented and understood. Furthermore, this thesis focuses on the socioeconomic determinants thus the biological causes are not discussed in more detail.

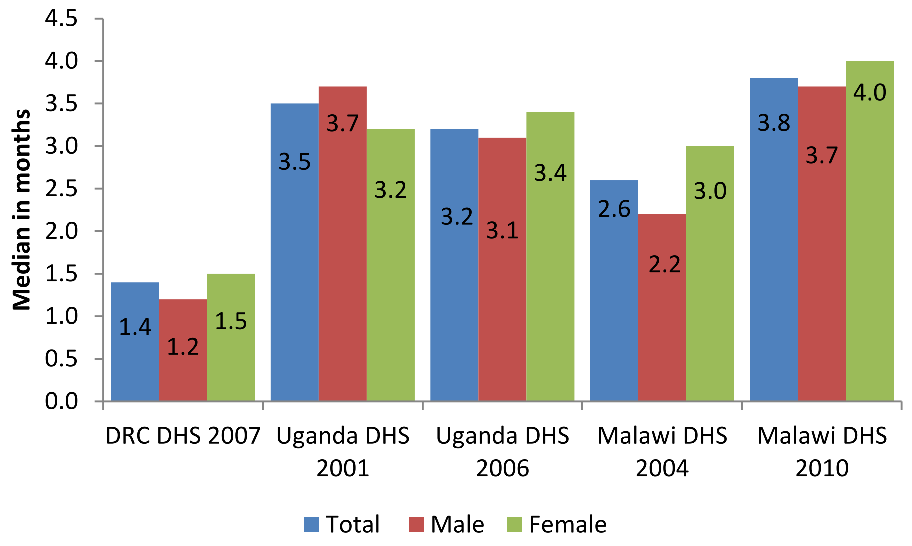
2.5.3. Physiological causes of anaemia

Physiological states such as pregnancy, menstruation and lactation are known to be related to anaemia. The mechanism through which anaemia can occur during pregnancy is explained in more detail in clinical literature (Banhidy, Acs et al. 2011; Beucher, Grossetti et al. 2011; Jougleux, Rioux et al. 2011; Bokhari, Derbyshire et al. 2012). Haemoglobin concentration, also known as haematocrit, and red cell counts fall during pregnancy. The reason is because of the expansion of the plasma volume which depends partially on iron status of the individual (Von Tempelhoff, Heilmann et al. 2008; Khalid and Ahmad 2012). During pregnancy a substantive quantity of iron is deposited in the placenta for the foetus resulting in an increased absorption of iron (Kell 2009). Women who enter their pregnancy with iron deficiency or who during pregnancy do not consume food rich in iron may become anaemic (Banhidy, Acs et al. 2011).

Lactation also results in loss of iron via breast milk (Katsios, Zoras et al. 2010). Lactating mothers have much greater iron requirements. This is because (1) they have to restore their iron losses from pregnancy and delivery and (2) meet the demands of infant requirement from iron through breast milk (Åkesson, Berglund et al. 2002). If the mother's diet is iron-poor at the time of lactation she might develop iron deficiency anaemia. In women the most common reason for iron deficiency is menstrual bleeding combined with poor diet.

Breastmilk is an important source of nutrients for newborns and infants and therefore can be linked to anaemia. The World Health Organisation recommends that infants should be exclusively breastfed during their first months of life in order to achieve optimal growth, development and health. After six months of life, to meet their nutritional requirements, infant should receive adequate and safe complementary foods while breastfeeding continues until they are two years olds or beyond (WHO 2007). Breastmilk contains not only sufficient iron but also adequate nutrition for infants up to six month, but breastmilk becomes insufficient after six months of life (Picciano 2001). Not all infants in less developed countries are exclusively breastfed from birth up to six months and receive safe complementary foods and, as a result, their health is compromised. The available literature suggests that only about 39% of infants in less developed world, 25% in Africa, are exclusively breastfeed for the first six month of life (Lauer, Betran et al. 2004; Kimani-Murage, Madise et al. 2011). In DRC, Uganda and Malawi, according to Demographic and Health Surveys, the median duration and frequency of breastfeeding for exclusive and full breastfeeding are very low in DRC, Uganda, and Malawi. There is some evidence of slight sex differential in the duration of breastfeeding. The median duration of breastfeeding is slightly lower for males than it is for females except Uganda (see Figure 2.1).

Figure 2.1 Median duration of exclusive and full breastfeeding among children under three years of age in DRC, Uganda and Malawi by sex



Source: ICF International, 2012. MEASURE DHS STATcompiler; http://www.statcompiler.com; December 15 2012

2.5.4. Pathological causes of anaemia

Pathological states, infectious diseases and illnesses in particular malaria, hookworm (ancylostomiasis or necatoriasis), schistosomiasis, HIV and other water-related infections in tropical climates are important factors contributing to the risk of anaemia (DeMaeyer 1990). In Ghana, it was found that there is a strong association between anaemia and factors such as malaria parasitaemia and hookworm infections (Brabin et al. 2001). Malaria parasitaemia is a major risk factor of anaemia for pregnant women, infants and young children. These individuals have reduced acquired immunity to infection (Bull and Marsh 2002). The development of acquired immunity leads to range-related changes in morbidity (and hence anaemia) due to infection (Menendez, Fleming et al. 2000). Malaria parasite (plasmodium species) causes anaemia through a number of mechanisms. Malaria parasite increases rates of destruction and removal of red blood cells, and decreases the rate of erythrocyte production in the bone marrow (Menendez, Fleming et al. 2000; Nwonwu, Ibekwe et al. 2009; Quintero, Siqueira et al. 2011). Other mechanisms through which malaria parasite causes anaemia are associated with acute clinical states including but not limited to the invasion of hemolysis of red blood cells, cytokine disturbance and dyserythropoeisis (Nussenblatt and Semba 2002). Plasmodium species have differing levels of pathogenicity. However, higher mortality and morbidity are caused by plasmodium falciparum (Craig, Snow et al. 1999). It should be noted that the anopheles mosquito is only the vector for plasmodium and is not the cause of malaria. The transmission or endemicity of malaria depends on the density and infectivity of anopheline vectors which depend on climatic, physical and population characteristic including but not limited to rainfall, location of human settlements near or at rivers or other mosquito larval breeding sites and the density of human populations (Craig, Snow et al. 1999; Snow, Korenromp et al. 2004).

Hookworm is significantly associated with higher risk of decreased haemoglobin (Brabin et al. 2001). Hookworms suck blood and cause bleeding to an extent that it reduces the amount of blood and decreases the absorbed amount of food. Hookworms are much more predominant in Sub-Saharan Africa. In 2005, 37.7 million women aged between 15 and 49 had hookworm and of these 6.9 million were pregnant (Hemminki and Rimpela 1991; Hokama, Takenaka et al. 1996; Brooker, Hotez et al. 2008; Smith and Tessaro 2009). Hookworm infection in pregnant women is associated with an increased risk of maternal anaemia and an increased low birth weight at delivery (Lu 2008). It is also argued that anaemia is strongly related with schistosomiasis (Mwapasa et al. 2009). Schistosomiasis is an important public health problem with an estimated 200 million cases reported each year and 85% of the cases are reported in Sub-Saharan Africa (Van der Werf, de Vlas et al. 2003). Schistosomiasis is endemic in DRC, Uganda and Malawi (Mwapasa et al. 2009). In Malawi it is estimated that between 40% and 50% of the total population is infected, about 50 % of the total population in Uganda, and between 35% and 50% in DRC (Lengeler, Makwala et al. 2000; John, Ezekiel et al. 2008; Kapito-Tembo, Mwapasa et al. 2009).

In pre-school children, it is also found that hookworms expose children to the risk of becoming anaemic. A case control study of anaemia in children found that malaria, hookworm infections and HIV infection are factors significantly associated with anaemia in pre-school children in Malawi (Desai 2000). In this study, cases were matched with controls using age. However, unconditional logistic-regression models were used for the analysis. Since each case was matched with at least one control, conditional multivariate logistic-regression models would have been preferable to unconditional ones. This is to say that the methods used to analyse the data are not well suited for this type of data. Therefore the results from this study need to be interpreted with caution.

Low haemoglobin can also be caused by gastritis, piles, stomach cancer, ulcers or bowel cancer and blood diseases such as leukaemia, although this type of anaemia might be rare in Africa (WHO 2006).

2.5.5. Socioeconomic and demographic related factors of anaemia

Socioeconomic, demographic and environmental factors are among other factors that could be related to anaemia and maternal/child health in general. Social risk factors associated with anaemia have not been reported widely and it is difficult to find published literature on this subject. Few studies have explored the links between socioeconomic factors and anaemia. Ngnie-Teta (2007) identified risk factors associated with moderate to severe anaemia in children in Benin and Mali at the individual, household and community levels, suggesting a positive link between maternal education, bed net use and the place of residence with moderate to severe anaemia in children. The results suggest that children of educated mothers, those children who slept under insecticide treated bed net and those children from urban areas are less likely to have anaemia compare with their counterparts.

The link between anaemia and higher maternal level education could further be explained by high income which is likely to be related to improved living conditions and health (Currie and Stabile 2003).

Beneficial effects of maternal education can also be explained though household income as argued in epidemiological studies (Reed, Habicht et al. 1996; Glanz and Rimer 2008). Education can influence eating habits and the choice of food (Stein and Fairburn 1996). Educated women can easily welcome advice or information about how to deal with changes in eating pattern. Malnutrition is argued to be a result of poverty. The richest can have access to medical care when needed or afford necessary food and be prevented from malnutrition (Valdivia 2004; Oldewage-Theron, Dicks et al. 2006). The use of insecticide treated bed net is argued to prevent malaria. The link between the use of a bed net and anaemia as suggested could be explain through malaria parasites which destroy red blood cells causing anaemia (Cowman and Crabb 2006).

In addition, this study suggests significant clustering effects at community levels (Ngnie-Teta, Receveur et al. 2007; Downs, Feinberg et al. 2009). The outcome anaemia was used as binary (moderate to severe as (yes) and mild and not anaemic combined, as (no)). Although clinical literature suggest that even mild anaemia can affect cognitive development of children, in the study by Ngnie-Teta (2006) the effects of mild anaemia on children wellbeing were completely ignored. Mild anaemia should not have been combined with non-anaemic cases because even mild anaemia can impair cognitive function of children (Karen 2003). These results should be interpreted for moderate to severe anaemia only.

Another study by Ngnie-Teta (2009) aimed to investigate socioeconomic risk factors associated with anaemia among women in Mali. The author, however, found that risk factors of anaemia vary whether it is mild, moderate or severe anaemia (Ngnie-Teta, Kuate-Defo et al. 2009). Both studies by Ngie-Teta yield similar results in term of socioeconomic risk factors associated with anaemia. Another study suggested that maternal nutritional education has had an impact on reducing other micronutrient deficiencies such Vitamin A, Vitamin B12 and folic acid. Maternal nutritional education has a positive input for iron deficiency anaemia especially for iron intakes and haemoglobin levels since it is suggested that iron supplementation is more effective with nutritional education (Galloway, Dusch et al. 2002). It is seen that women recognise anaemia related symptoms. However, few consider these as a priority health concern because of lack of knowledge on the consequences associated with anaemia (Galloway, Dusch et al. 2002).

In Ghana, it was found that in women, besides well-known related causes of anaemia such as malaria parasitaemia, hookworm infections and pregnancy, there is a strong association between anaemia and women's age, parity and the place of residence (Brabin et al., 2001). The relationship between age and parity and anaemia can be explained through physiological factors such as pregnancy and menstruation. Women with multiple births (high parity) might have been through multiple pregnancies and therefore an increased risk of anaemia. The link between the place of residence and anaemia could merely be explained by seasonal variations, which can impact on food production and availability especially in rural areas of developing countries. It is argued that in rural areas in less developed countries the critical period during which nutritional status are impaired is around the end of the rainy season for subsistence farmers and the dry season for pastoralists (Simondon, Benefice et al. 1993). This is because of seasonal food shortage.

The link between bed net use and anaemia is because of the strong relation between anaemia and malaria (Steketee, Nahlen et al. 2001). In a study that reviewed 11 randomised clinical trials it was found that in the majority of developing countries with high malaria transmission, insecticide treated materials could reduce the burden of maternal and childhood deaths (D'Alessandro 2001). Bed net use, a proxy for malaria prevention, appears to be an important factor not only for maternal and childhood health but also for the health of other household members. In the Kilombero valley in Tanzania, the use of a bed net had a dramatic impact on anaemia in children under the age of 2 years (Sochantha, Hewitt et al. 2006). Community randomised controlled trials, conducted in a range of Sub-Saharan countries, suggested that the use of treated bed nets could contribute up to 30% reduction in all causes of child mortality in Africa (Eisele, Lindblade et al. 2005). Insecticide-treated nets have been found to be cost effective in the prevention of maternal and childhood illnesses and deaths in countries such as Kenya, Malawi and Tanzania (Schellenberg, Abdulla et al. 2001; Holtz, Marum et al. 2002; Lines, Lengeler et al. 2003).

Individual background factors of anaemia among children are age, birth order, birthweight and sex (Schellenberg, Schellenberg et al. 2003). It is suggested the risk of anaemia varies from males to females and by age groups and anaemia is much more prevalent among males between the age of 0-4 years and females above the age of 5 years (Murray and Lopez 1997). The relationships between sex and age and anaemia have also been suggested for other child nutritional status such as weight-for-age and height-for-age z-scores and might be due to biological factors which this thesis might not be able to explain (Madise, Matthews et al. 1999).

2.5.6. Health and socio-economic indicators in the DRC, Uganda and Malawi

This section provides some background information about DRC, Uganda and Malawi in terms of key health and socio-economic indicators and geography. DRC, Uganda and Malawi are located in Sub-Saharan Africa. The climate is tropical in the DRC and Uganda and subtropical in Malawi. The Tropical/subtropical climate is typified by heavy rain and hot temperatures. In all three countries, the rainy season runs from October through April. It is normally hot and humid in the months of November to April and hot, dusty and very dry in the months of July to November. The other characteristics of the tropical climate include but are not limited to disease carrying insects that breed in standing pools of water (McMichael and World Health Organization 2003). Table 2.8 presents key health and socio-economic indicators for each of the three countries and for the Sub-Saharan Africa as a whole between 2000 and 2012. The data indicate that

DRC has higher infant and under-5 mortality rates, and higher proportion of underweight compared with Uganda and Malawi. DRC has the lowest GDP per capita in Sub-Saharan Africa and in the world (Go and Page 2008).

Table 2.8 Health and socio-economic indicators by country

Key Indicators	DRC (DHS 2007)	Uganda (DHS 2006)	Malawi		Sub-Saharan Africa
			(DHS 2004)	(DHS 2010)	
Health					
Infant mortality (per 1000 live births)	92	71	76	66	77
Under-5 mortality (per 1000 live births)	148	128	133	112	129
Percentage of child immunised	30.6	46.2	64.4	80.9	69.0
Exclusive breastfeeding rate (2000-2007; 0-6 months)	36	60	57	71	32
Timely complementary feeding rate (6-9 months)	82	80	86	89	68
Median duration of exclusive breastfeeding	1.4	3.2	2.6	3.8	3.5
Percentage stunted	45.5	38.1	52.5	47.1	42.0
Percentage wasted	10.0	6.1	6.0	4.0	9.7
Percentage underweight	24.0	15.9	17.0	12.8	25.0
Reported malaria cases in 2010[2]	7,439,440	11,080,045	-	6,851,108	-
Socio-economic					
GDP per capita (US $)[3]	400	1,300	210	900	1,424
Percentages of literate women[3]	58.9	56.3	62.4	67.6	68.4

Sources: ICF International, 2012. MEASURE DHS STATcompiler; http://www.statcompiler.com; December 15 2012
2 Global Health; http://www.globalhealthfacts.org/data/topic/map.aspx?ind=30 , December 15 2012
3 World development Indicators 2012.

2.6. Conceptual framework

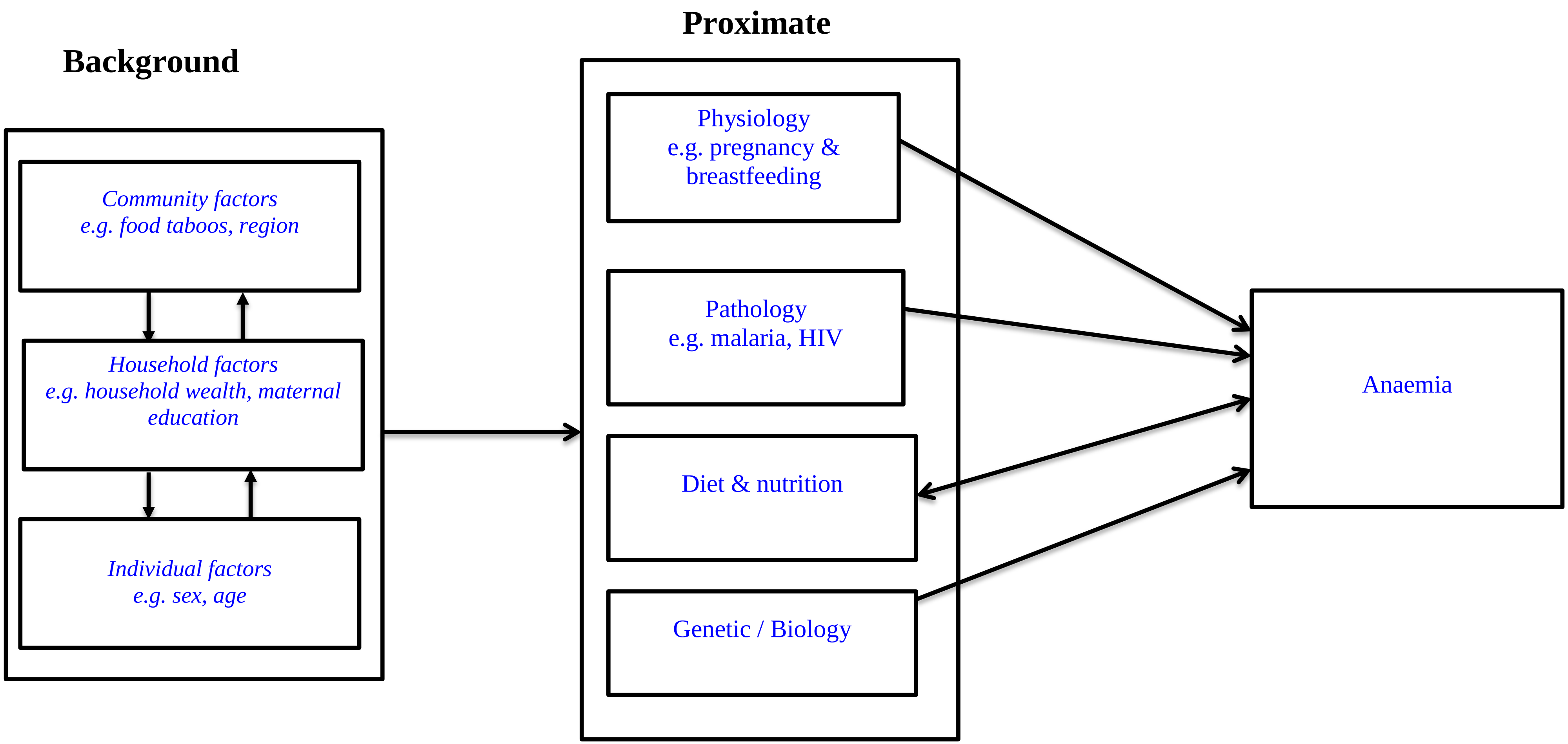
The conceptual framework (see Figure 1), which is used as a guideline for this thesis, depicting how the socio-demographic and proximate determinants act on a person's (child/woman) risk of having anaemia is derived after the literature review. The present conceptual framework accounts for the hierarchical nature of anaemia related factors and highlights the pathways through which they might influence the person's risk of developing anaemia. Anaemia is multifactorial and its related causes may be classified according to their position in the pathophysiological process as presented in the conceptual framework (Kahigwa, Schellenberg et al. 2002). Socioeconomic and demographic and environmental factors such as poor living conditions, education and social and cultural norms such as food taboos may be important underlying factors and can predispose the individual to anaemia. All these Socioeconomic and demographic factors have been grouped as background characteristics. More immediate factors in the pathophysiological process are physiological, pathological, biological (genetic) and nutritional (diet) factors. Immediate factors are depicted in the conceptual framework as proximate factors.

The conceptual framework begins by presenting background socioeconomic, demographic and environmental factors which are divided into three groups: community; household; and individual related factors. All these factors operate indirectly through some proximate factors to influence the person's risk of having anaemia (Mosley and Chen 1984). Community related factors include the place and region of residence and water source. Living in a rural or urban area, in specific region of the countries are important potential factors for children's or women's health status. Other community related factors are health seeking behaviour and sociocultural which includes cultural norms such as food taboos. Most communities in Sub-Saharan Africa have food taboos and the highest level of dietary restriction occur during the time when people need greatest sustenance (White 2002). For example during pregnancy, lactation and the physiological growth period of children some type of foods are prohibited. Although some of the community factors are not directly observable, through the operationalization of this conceptual framework however, unobserved community factors will be accounted for using appropriate methods such as random effect models and endogenous switching models. Household wealth status, maternal level of education, electricity and sanitary facilities are household related factors. Individual related factors can include age, sex, weight at birth and succeeding birth intervals.

Proximate determinants are the conditions that can directly expose the person to anaemia. These are in turn divided into four groups: physiological;

pathological; biological (genetic); and nutritional (diet) factors as discussed above. Physiological factors are pregnancy and breastfeeding. Pathological factors include all the other major diseases (e.g. malaria, diarrhoea and HIV). The factors within boxes named ‘Background’ and ‘Proximate’ might be interrelated and all factors are not listed in the conceptual framework, but will be described in more details in the next chapter. One headed arrows in the conceptual framework indicate the direction of the relationship between factors in that box and the other box. For example, the headed arrow between background characteristics and proximate determinants of anaemia means that some factors listed as background characteristic can influence some proximate determinants. For example, food taboos can expose children or women to anaemia through diet. It should be noted that the arrows used in this conceptual framework do not specify statistical models like in graphical chain modelling, but the potential directions and pathways through which some factors might influence others factors. A two headed arrow indicates reciprocal relationships. This conceptual framework will be operationalized throughout this thesis.

Figure 2.2: Conceptual framework for anaemia and its related factors



Note: Background characteristics (Socioeconomic, demographic & environmental factors)
Proximate determinants

2.7. Review of interventions for anaemia control and prevention

For many years, anaemia has been recognised as a public health concern. However, little progress has been made in reducing anaemia and the global prevalence of anaemia is still high. When anaemia is diagnosed and treated at an early stage the person can be cured without any complications. Personal illness control is a preventive guide to promote children or women's health. These include obtaining iron supplements when necessary, a regular use of iron fortified food in the household or an appropriate diet, the use of foods that enhance absorption or utilisation of iron, food from animal and non-animal origin, fruits, vegetables, and tubers that are rich in vitamin A, C, and Folic acid. Anaemia is multifactorial; it is due to both poor diet and poor health. Effective preventive measures for anaemia control include food-based approaches and iron supplementation where necessary. Food-based approaches address food preservation, processing, marketing, and preparation of food, feeding practices, food distribution within regions or families, and care for vulnerable groups (Khor 2008; Oliva, Pinnow et al. 2008).

Food fortification is especially important for preventing and treating iron deficiency anaemia, and it is an effective long-term approach to improving the iron levels in a population. Although this requires a cooperative effort between governments, food industry and consumers, food fortification has demonstrated successful improvement in the iron status of populations in many countries. For example, rice in the Philippines and Sri Lanka (Hettiarachchi, Hilmers et al. 2004) is fortified with ferrous sulphate. In Chile, iron fortifications are added to flour during the milling process (Darnton-Hill, Mora et al. 1999). In other countries such as Sweden, UK and USA, where flour is stored for a long time, metallic iron is used (Martínez-Navarrete, Camacho et al. 2002; Baltussen, Knai et al. 2004). These measures have been successful in the countries listed above because these are evidence based measures, and are tailored to local conditions. The challenge with food fortification is to find the type of food consumed by all age groups, affordable and iron that will not alter the taste of the food.

Since almost 50% of anaemia is the result of iron deficiency, interventions to prevent and combat iron deficiency include iron supplementation to vulnerable segments of the population (McClung, Marchitelli et al. 2006). Since both an excess and inadequate iron supply is associated with some health risks (Meier, Nickerson et al. 2003), and can interfere with the absorption of other nutrients and impairs cellular function, it is suggested that iron supplements be carefully administered and regulated to promote an optimal condition that preserves children's or women's health (Iannotti, Tielsch et al. 2006).

There is an open debate about whether iron should be supplied by oral supplementation or through intravenous methods. Some clinical trials (Iannotti, Tielsch et al. 2006) argue that an oral iron supplementation may be limited due to poor iron absorption and that intravenous administration of iron is more effective. A randomised control trial aiming to compare the effectiveness of oral and intravenous iron administration for treating iron deficiency anaemia in women in Mexico and the United States of America found that intravenous administration of iron is safe and effective in postpartum anaemic women who recover early from anaemia compared with those on oral supplements (Van Wyck, Martens et al. 2007). However, a study that reviewed 26 randomised control trials of preventive oral iron supplements suggests that oral iron supplements have positive health benefits (Iannotti, Tielsch et al. 2006). Although the provision of daily iron supplements is widely recommended and is used for improving iron status its effectiveness has been limited due to its side effects such as nausea, constipation and staining of teeth in children. For children for example, it is proposed that one, two or three times a week on non-consecutive days of intermittent iron supplementation is effective and safe alternative to daily supplementation (De-Regil, Jefferds et al. 2011).

In most developing countries and in Sub-Saharan Africa in particular little effort is made to prevent anaemia. The existing preventive measures are focused on controlling anaemia-related infections and breastfeeding practices. These include encouraging mothers to breastfeed their infants, prevention and control of infectious diseases such as tuberculosis, HIV/AIDS and agent factors such as hookworms, treatment of hookworms and other helminth infections and malaria control (Keusch 1982). Control measures for anaemia, where available in Sub-Saharan Africa, focus on treating some vulnerable population groups such as pregnant women and children attending antenatal visits (Darmstadt, Walker et al. 2008). Not every pregnant woman in Sub-Saharan Africa, however, attends antenatal visits.

Communication strategies that address behaviour changes are important including nutritional education. Effective nutritional education is also important in providing information on health and nutritional state for both supply and demand programmes when assessed under local conditions (WHO, 2002). Other actions include parasitic diseases control programmes such as treating hookworms, schistosomiasis and malaria control (through the use of bed net), and improving farming systems that enable not only the production but also the availability and the distribution of foods.

2.8. Summary

The aim of this chapter was to review the literature on anaemia in order to understand its related factors, health and economic consequences associated with anaemia for women and children, and to identify gaps which need to be filled. The literature states that anaemia remains one of the most severe and critical nutritional disorders in the world today. Anaemia is much more prevalent in less developed countries; Sub-Saharan Africa has the highest prevalence while Asia has the highest number of people suffering from anaemia. Iron deficiency anaemia, which is the most prevalent type, represents half of anaemic population. Although children and women are the most vulnerable, anaemia affects also males and females of every age. Anaemia impairs the cognitive development of children from infancy through to adolescence. It damages the immune system and is associated with increased morbidity. Anaemia is also associated with multiple diverse outcomes during pregnancy not only for mothers but also for their children. The health consequences of anaemia in children may be irreversible even after treating the anaemia. Malaria, hookworms, diarrhoea and other water related diseases also expose women and their children to the risk of anaemia. Anaemia is multifactorial and its causes can be classified according to their position in the pathophysiological process. Socioeconomic and demographic factors are important underlying factors which could predispose the individual to the risk of anaemia through proximate factors such as biological, nutritional and pathological factors. The link between child nutritional status and anaemia need further investigations using not only appropriate methods but also representative samples. It is found that biological related causes of anaemia are well documented. However, socioeconomic and demographic factors associated with anaemia are not widely reported possibly because of the lack of representative data. It is even difficult to find published literature on social risk factors for anaemia. Few published studies use hospital based data to report the prevalence of anaemia particularly in women attending antenatal care. Therefore, this thesis will explore socioeconomic and demographic factors associated with anaemia in children and women.

CHAPTER 3
Data and methods

3.1. Introduction

This chapter describes the data and methods used in Chapter 4, 6 and 7. There are three sections to the chapter. Section one describes each individual country's data from the survey design to the sample selection and explains the motivation in choosing these countries. Section two describes the outcome and predictor variables and indicates how they are recoded. The section also operationalizes the conceptual framework. Section three presents standard statistical methods used in Chapters 4, 6 and 7 from model selection to the interpretation of results. For clarity reasons other methods used are described at the beginning of each chapter.

Justification of the countries

The environmental and economic conditions place an extra burden on the nutritional status of women and children. Poverty affects the quality of diet. Infections and poor quality diets create an ideal environment for malnutrition, which further predisposes women and children to morbidity and mortality. Of the 25% of the world anaemic population, 90% are from developing countries. Although Asia has the greatest number of individuals with anaemia, the prevalence of anaemia is higher in Sub-Saharan Africa. This is the reason why the proposed study focuses on Sub-Saharan African countries. But because of limited time, only three Sub-Saharan countries are included in the analysis. This included one country from central Africa (DRC) without studies on anaemia, one from Eastern Africa (Uganda) with few studies on anaemia and the other from South-East Africa (Malawi) with few public health attentions toward anaemia. DRC was chosen because the 2007 DHS is the first and unique DHS ever collected in this conflict zone. Hence, no previous study has looked at the prevalence of anaemia in this country. This study could be the first to investigate the prevalence of anaemia in DRC and explore risk factors associated with this health threatening disorder. In addition, DRC and Uganda are both countries experiencing conflicts and could be compared with Malawi where there are no conflicts. The few studies published on anaemia among women and children in Malawi and Uganda use hospital based data and focus on biological aspects of the disease (Klarberg and Wynder 1989). It is argued that biological conditions might be exacerbated by environmental and socioeconomic situations which surround the individual (Klarberg and Wynder 1989). This study will explore socioeconomic and demographic factors associated with anaemia in children and women in the three countries.

3. 2. Data and the selected factors

This section describes and discusses the data used for this study. Four nationally representative data from the 2006 Uganda, 2007 Democratic Republic of Congo, and 2004 and 2010 Malawi Demographic Health Surveys are used. The four surveys are complex surveys involving multistage sampling. The sample design involved probabilistic two-stage sampling. Samples in all three countries were split into urban and rural areas.

Countries are divided into stratums (e.g. district) and each stratum into clusters (e.g. villages), clusters were randomly selected from each stratum and households were randomly selected from the selected clusters. Those women and children within households selected for the male interview (that is, every one in three households) were tested for anaemia.

3.2.1. Uganda Demographic Health Survey (UDHS) 2006

The 2006 UDHS is the first UDHS which includes the entire country. In the previous surveys some groups or districts were excluded for security problems (National Statistical Office and Macro 2007). The 2006 Uganda Demographic Health Survey is a representative probabilistic sample where the country was divided into 9 stratums (e.g. regions), each stratum was divided into clusters, where 368 were randomly selected. Approximately 15-20 households were randomly selected from a completed sample frame of households and a total of 9,864 households were selected. The northern region was oversampled to provide estimates for Karamoja district and internally displaced persons camps; a detailed sampling methodology can be found in the 2006 Uganda Demographic Health survey final report (National Statistical Office and Macro 2007). Women in households selected for male interview (every one household in three), aged 15-49 (permanent resident or not) present on the night of the interview were eligible to be tested. From those 9,864 households, 2,928 women were eligible for anaemia testing, out of which 2,817 women were tested for haemoglobin levels (anaemia) giving a response rate of 96%. In addition, 2,110 children aged less than 5 years present in the selected households (households selected for male interview) were tested for anaemia (see Table 3.1.a).

Table 3.1.a Description of the 2006 UDHS household and individuals interviews

	Residence		
Results	Urban	Rural	Total
Household			
Households selected	1,637	8,227	9,864
Households occupied	1,496	7,603	9,099
Households interviewed	1,390	7,480	8,870
Household response rate	92.9	98.4	97.5
Women			
Eligible women	1,577	7,429	9,006
Eligible women interviewed	1,450	7,081	8,531
Eligible women response rate	91.9	95.3	94.7
Anaemia tested			
Women			
Selected women	493	2,435	2,928
Selected women tested	447	2,370	2,817
Women tested response rate	91	97	96
Number actually used for analysis[1]	447	2,370	2,817
Children			
Selected children	217	1,893	2,110
Children tested	217	1,893	2,110
Children response rate	100	100	100
Number actually used for analysis[1]	217	1,893	2,110

Source : National Statistical Office and Macro (2007)

1 indicates the total number that was used for analysis in Chapters 4, 6 and 7

3.2.2. Democratic Republic of Congo Demographic Health Survey 2007

The 2007 Democratic Republic of Congo Demographic Health Survey is the first nationally representative survey conducted in DRC. The sampling methodology involved a probabilistic two stage sampling. The country was divided into 34 stratums; each stratum was divided in clusters. 300 clusters (123 from urban and 177 from urban areas) were randomly selected. 9,000 households (3,690 from urban and 5,310 households from rural areas) were randomly selected, with 30 households per cluster. 4,690 women from the selected households, present on the night of the interview were selected for haemoglobin level measures (anaemia). Of these women, 4,156 were tested giving a response rate of 99%. Children aged between 6 and 59 months (3,656 children) present in households selected for male interview (every one household in two) were eligible for anaemia testing, but only 3,159 were tested for anaemia, yielding a response rate of 86% (See Table 3.1.b).

Table 3.1.b: Description of the Democratic Republic of Congo Demographic Health Survey 2007

	Residence		
Results	Urban	Rural	Total
Clusters	123	177	300
Household			
Households selected	3,690	5,310	9,000
Women			
Eligible women	4,789	5,206	9,995
Anaemia tested			
Women			
Selected women	2,251	2,439	4,690
Selected women tested	2,208	2,424	4,632
Women tested response rate	98.1	99.0	98.8
Number actually used for analysis[1]	2,208	2,424	4,632
Children			
Selected children	1,499	2,157	3,656
Children tested	1,286	1,873	3,159
Children response rate	86.0	86.8	86.4
Number actually used for analysis[1]	1,286	1,873	3,159

Source: National Statistical Office and Macro (2008)
1 indicates the total number that was used for analysis in Chapters 4, 6 and 7

3.2.3. Malawi Demographic Health Surveys 2004 and 2010

The 2004 and 2010 Malawi Demographic Health Surveys are nationally representative samples. These surveys are stratified two-stage sampling design. The country was divided into stratums (districts). Each district was divided into enumeration areas also known as clusters. Clusters were randomly selected and households were randomly selected from clusters. In 2004, 15,041 households (1,984 from urban and 13,057 from rural) were randomly selected from 522 clusters (64 in the urban and 458 in the rural areas), also selected randomly from the stratums. Of the 12,229 women who were eligible to be interviewed 2,960 women of reproductive age were selected for haemoglobin measures. 2,749 women were tested for anaemia, with a response rate of 93%. 2,438 children present in the households that women were selected were eligible and 2,329 were tested for anaemia (see Table 3.1.c).

The 2010 Malawi Demographic Health Survey included 849 clusters (158 in urban areas and 691 in rural areas). The allocation of clusters did not use proportional allocation in order to avoid under representation of districts with few clusters. Some stratums (districts) from the Northern region were oversampled to account for smaller population size. In most districts in Malawi, more than 90% of the population resides in rural areas (National Statistical Office and Macro 2005). Therefore, urban areas were also oversampled. All women of reproductive age and children aged between 6-59 months in one-third of all households, who voluntarily agreed to give blood, were tested for anaemia. In total, 7,290 women and 2,799 children were tested for anaemia in 2010.

Table 3.1.c: Description of the Malawi Demographic Health Survey 2004

Results	Residence		
	Urban	Rural	Total
Household			
Households interviewed	1,984	13,057	15,041
Household response rate	95.8	98.5	97.8
Women			
Eligible women	1,733	10,496	12,229
Anaemia tested			
Women			
Selected women	369	2,465	2,960
Selected women tested	358	2,391	2,749
Women tested response rate	97	97	93
Number actually used for analysis[1]	358	2,391	2,749
Children			
Eligible children	234	2,204	2,438
Children tested	209	2,120	2,329
Children response rate	89	96	96
Number actually used for analysis[1]	209	2,120	2,329

Source: National Statistical Office and Macro (2005)
1 indicates the total number that was used for analysis in Chapters 4, 6 and 7

For the analysis of weight-for-age z-scores and anaemia in children, it should be noted that sample sizes in Tables 3.1 a, b and c are further reduced in Chapter 5 because weight-for-age z-scores values are missing, only those children with weight-for-age z-scores and haemoglobin values are included.

Weighting and representativeness of the Demographic and Health Surveys (DHS) from DRC (2007), Uganda (2006) and Malawi (2004 and 2010)

Demographic and Health Surveys (DHS) allocate samples between urban and rural areas using power allocations such as proportional and equal size allocation. A power value is applied to achieve satisfactory sample size. In most of DHS, some large stratums (e.g. districts or region) are undersampled and small stratums are oversampled to achieve accurate representation of each stratum. For example, urban areas are oversampled to ensure that the survey precision is comparable across urban and rural areas. Oversampling or undersampling any stratum does not pose any problems for representation if sample weights are properly calculated and applied in tabulation (Campbell and Berbaum 2010). Sample weights were provided with the three datasets described above and were applied for all tabulation and for initial model exploration.

Data from the three countries as described above are complex survey data involving multistage sampling. The sample design involved probabilistic two-stage sampling where stratification is used during the survey design. Therefore appropriate methods will be used were possible to account for complex survey design (Rabe-Hesketh and Skrondal 2006). Weighting is required to obtain representative estimates of the results. However, applying weights when using multilevel modelling techniques is difficult provided the weights are given for different levels in the models. In situation where weights are known at different levels sample weighting for continuous response models will be unbiased, but the estimates still biased for discrete response models (Chambers, Sugden et al. 1998; Pfeffermann, Skinner et al. 1998; Rabe-Hesketh and Skrondal 2006).

3.3. Variables in the models

3.3.1 Outcome variable

The outcome variables used in this thesis are anaemia which was diagnosed through the haemoglobin level testing (measured in g/dl) and weight-for-age z-scores (standard deviations). Weight-for-age z-scores were computed using children's anthropometric measurements (weight and height), age and sex. The World Health Organisation Anthro software v3.22 was used to calculate the weight-for-age z-scores (WHO 2007).

The ranges of haemoglobin values for both children and women and weight-for-age z-scores ranges for children were investigated; outlying values were removed as depicted in Appendices 3.1 & 3.2. After checking the distribution of haemoglobin level in women, the data suggested that haemoglobin level is not normally distributed in all three countries (see Appendix 3.3). The variable haemoglobin was transformed but none of the transformation followed a normal distribution. Furthermore simple linear regression models were fitted using haemoglobin level as the outcome against some explanatory variables (age, BMI, region), the residuals were plotted in order to choose a suitable model for the data. The residual plots, however, showed non-normality (see Appendix 3.8). Therefore, anaemia level for women was categorised as binary (anaemic or not anaemic) in Chapter 6 and 7. Haemoglobin levels of less or equal to 11.99 g/dl was classified as anaemic and haemoglobin of above 11.99 g/dl as not anaemic for women pregnant or not (WHO 1989).

The distribution of children's haemoglobin levels (anaemia) was first checked before and after removing outlying values (see Appendices 3.3 & 3.5), simple linear regression models were fitted and the residuals were further investigated. The residuals are not normally distributed (see Appendix 3.6). Since clinical studies argued that the effect of anaemia on children's health and development varies with the levels of anaemia, haemoglobin levels were categorised using its ordinal scales as suggested by the World Health Organisation (WHO 1989). For children, anaemia was recoded as severe (haemoglobin concentration below 7 g/dl), moderate (the concentration is between 7 and 10 g/dl) and mild (when the concentration is above 10 and below 11 g/dl), and none (when the concentration is above 11 g/dl), an ordinal scale in the analysis in Chapter 4 (WHO 1989). This is because the state of moderate is more critical than that of mild and the state of severe is more critical than that of moderate. However, since there were few observations in the severe category, moderate and severe were combined to form one category. The distribution of weight-for-age z-score was also checked, simple regressions were also fitted and residuals were further investigated. Since residuals are approximately normally distributed for all three countries (see Appendix 3.11), weight-for-age z-scores is used on its original continuous scales.

3.3.2 Indicator variables

Potential socioeconomic and demographic risk factors selected as predictors in the analysis presented here are considered at the individual, household and community levels (background characteristics) as depicted in the conceptual framework (Figure 2.2). Potential socioeconomic, demographic and environmental factors, proximate factors and their categorisation for children and women are presented in Tables 3.2 and 3.3 respectively.

For children, age, sex, preceding and succeeding birth intervals, weight and size at birth are among individual factors. Children's birth weights were read from birth certificates or reported by their mothers. Birth weight was categorised into low birth weight (<2500g), normal weight (2500g and 3500g), high birth weight (>3500g), not weighted at birth or missing (Oddy, Li et al. 2006). For those children who did not have their birth weights recorded, the mother's perception of a baby's size at birth was recorded. It is important to note that the child's size at birth was self-reported and the information could be influenced by memory bias (Serra, Yamamoto et al. 2002).

It is argued that child malnutrition deficit is very marked between the ages of 1-2 years old (Mukaya, Ddungu et al. 2009). Children's age in months was used as continuous but also was grouped, <2 years and 2-5 years old. It is important to stress that for other variables, categories with few observations were grouped together to avoid wider confidence intervals. Maternal education and occupation, toilet facility and household wealth status are household related factors. Different categories of toilet facilities were grouped into three categories (flush, pit/bucket and none). Principal component analysis was used to derive a proxy of household wealth from household possession such as radio, TV, bike, car, truck, house roof material and floor, separately for urban and rural areas (Kolenikov and Angeles 2009).

Community factors included the place of residence, the source of drinking water and region. The reason why the source of drinking water was classified as a community factor is because some communities drink from the same sources such as public taps, standpipes and tube wells. Categories of the source of drinking water were recoded to group similar categories or categories with few observations into piped and others.

For children, maternal anaemia status, categorised as binary was used to predict children's risk of having anaemia and was classified as maternal related factor with maternal smoking habits. Whether the child had fever or diarrhoea and vaccination were classified as health related factors. With reference to the conceptual framework (Figure 2.2) fever or diarrhoea represent pathological related factors. Although fever is not merely a result of malaria, fever has been used as a proxy for malaria (Barat, Palmer et al. 2004; Uzochukwu and Onwujekwe 2004). Nutritional factors (known as diet in the conceptual framework), include the consumption of green leafy vegetables and red meat and whether the child was breastfed. The dummy variable ever breastfed was derived by combining those children who were exclusively breastfed and at least breastfed.

For women, current age, age at first birth, parity, BMI and smoking habits are individual related factors. BMI was recoded using international classification of BMI for adults (Lundgren and Mocroft 2003). A BMI of <18.50 kg/m^2, as underweight, between 18.50 and 24.99 kg/m2 as normal, ≥ 25 kg/m2 as overweight and ≥ 30kg/m2 as obese. Women physiological factors such as pregnancy and breastfeeding (see conceptual framework) can also be classified as individual factors. Women and their partner's education, women's occupation, marital status, bed net, electricity facilities, household wealth are among household related factors. For women, community related factors include the place of residence, the source of drinking water and region.

Table 3.2 Definition of variables for children

Individual level factors		**Household level factors**		**Other factors**	
Variable	Category	Variable	Category	Variable	Category
Age (continuous)				**Community level factors**	
Age		Maternal education		Place of residence	Rural
	< 2 years		None		Urban
	2-5 years		Primary		
Sex			Secondary	Water source	Other
	Female	Maternal occupation			Piped
	Male		Not working	Region	
Preceding birth interval			Prof & management	**Maternal factors**	
	First births		Clerical & sales	Smoking habit	No
	<24 months		Agriculture		Yes
	24-35 months		Services/ manual	Mother anaemic status	No
	36+		Domestics		Yes
Birth weight			Others	**Nutritional factors (diet)**	
	Low (>2500 g)	Toilet facility		Ever breastfeed	No
	Normal (2500g-3500g)		Flush		Yes
	High (>3500g)		Pit/bucket	Ate red meat	No
	Not weighed at birth		None		Yes
	Missing/DK	Wealth status		Ate green leafy vegetables	No
Succeeding birth interval			Poorest		Yes
	<24 months		Poorer	**Health factors**	
	24-35 months		Middle	Had fever in last two weeks	No
	36+		Richer		Yes
	Last births		Richest		DK
				Had diarrhoea in last two weeks	No
Child size	Very large				Yes
	Larger			Vaccination	No
	Average				Yes
	Small				

Table 3.2 Definition of the variables for women

		Household level factors		Community level factors	
Variable	Category	Variable	Category	Variable	Category
Individual level factors **Current age**		**Education**	None	**Place of residence**	
	15-24		Primary		Rural
	25-34		Secondary+		Urban
	35+	**Occupation**	Not working	**Water source**	
Age at 1st birth			Prof & management		Piped/Tape
	<15		Clerical & sales		Wells/Spring
	15-19		Agriculture		Others
	20-24		Household/domestic	Region (administrative regions are used)	
	25+		Services		
Parity			Others		
	Zero				
	One	**Marital status**	Never married		
	Two		Married		
	Three+		Widowed/separated		
BMI		**Partner education**	None		
	Low (<18.0)		Primary		
	Normal (18.0-24.9)		Secondary+		
	Overweight (25.0-29.9)		No Partner		
	Obese (≥30.0)	**Bed net use**	No		
Smoking habit			Yes		
	No	**Wealth status**	Poorest		
	yes		Poorer		
Physiological factors			Middle		
Pregnancy			Richer		
	No		Richest		
	Yes	**Electricity**	No		
Currently breastfeeding			Yes		
	No		Not de jure		
	Yes				

3.4. Statistical methods

A range of statistical methods are used in this thesis. For clarity reasons, certain methods will form an integral part of each chapter. However, standard methods will be explained in this chapter. The standard modelling techniques used are multilevel logistic and multilevel ordinal regression models. Multilevel logistic regression models are used in Chapter 6 and 7. Multilevel ordinal regression models are used in Chapter 4. Multilevel models are used to account for complex sampling design as described above. Endogenous switching regression methods are used in Chapter 5 and will be explained within that chapter before presenting the results.

A combination of forward model selection, practicality, and the principle of coherency were used for multilevel ordinal and logistic regression models where variables were entered one by one after they have been tested. The initial models were fitted with the outcome and the first explanatory variable. If the variable was significant at 5% significance level, a second predictor was added in the model. After adding the second explanatory variable in, if both the first and second predictors were found to be significantly related with anaemia an interaction term was added to check whether differences in the odds of anaemia observed among the levels of the first predictor vary according to the levels of the second predictor where necessary (if judged meaningful). For example, a model for anaemia among children with predictors such as age (less than 2 and between 2 and 5 years olds), gender (male and female) and mother anaemic status (yes anaemic and not anaemic), will begin with anaemia and age only, if age is significantly related with anaemia then gender will be added into the model. If both age and gender are significantly related with anaemia an interaction term will be added to check whether the odds of anaemia observed among males and females children significantly differ whether they are less than two years olds and between 2 and 5 years olds. If the interaction was significant at 5% level it was left in the model and a third predictor, let us say mother’s anaemic status for instance, was added in the model. If the third predictor was significant, interaction terms were also added into the model between the third variable and the first/second. Only variables or interaction terms which were significant at 5% level were left in the model and included in the final models.

3.4.1. Multilevel logistic regression model

Model specification

Let $\pi_{ijk} = p(y_{ijk}) = 1$ be the probability that a woman or child (i) in the household (j), from the community (k) is anaemic. With $y_{ijk} = 1$ if a women is anaemic and $y_{ijk} = 0$ if not. This probability can also be defined as a function of the intercept and of the predictor variables as follows:

$$logit(\pi_{ijk}) = log\left(\frac{\pi_{ijk}}{1-\pi_{ijk}}\right)$$
$$= \beta_{0jk} + \beta_1 x_{1ijk} + \beta_2 x_{2ijk} + \beta_3 x_{3ijk} + \cdots + \beta_n x_{nijk} \quad (3.1)$$

with $\beta_{0jk} = \beta_0 + u_{0jk}$.

In this equation, β_{0jk} indicates that the intercept is modelled as random at j^{th}(household) and k^{th}(community) levels. The variables x_{1ijk} to x_{nijk} are the explanatory variables and their coefficients are fixed effects. The intercept consists of two parts a fixed term β_0 and the random term u_{0jk}. The standard assumption is that the response y_{ijk} follows a Binomial distribution (1, π_{ijk}). In general form, this distributional assumption can be written as $y_{ijk} \sim Binomial(n_{ijk}, \pi_{ijk})$. In this case, n_{ijk} are all equal to 1 for binary analysis. This standard distributional form is also used to model proportions, where each proportion y_{ijk} is based on n_{ijk} observations with the same n_{ijk} denominator which in this special case is equal to 1 (Lindstrom and Kiros 2007). The estimation procedure was implemented using MLwIN 2.20. This procedure uses a linearization method, based on Taylor series expansion that transforms a discrete response model into continuous response. After applying the linearization, the model is estimated using Restricted Iterative Generalised Least squares (RIGLS) and predictive quasi-likelihood (PQL) methods.

3.4.2. The interpretation of coefficients for the multilevel logistic regression models

The coefficients from equation 3.1 are interpreted by taking the exponential of both sides of the model as follows:

$$\frac{\pi_{ijk}}{1-\pi_{ijk}} = e^{\beta_0} \times e^{\beta_1 x_{1ijk}} \times \ldots \times e^{\beta_n x_{nijk}}. \qquad (3.2)$$

Using a multiplicative effect, for one unit increase in x we obtain

$$\frac{\pi_{ijk}}{1-\pi_{ijk}} = e^{\beta_0} \times e^{\beta_1 (x_{ijk}+1)} \times \ldots \times e^{\beta_n (x_{nijk}+n)} = e^{\beta_0} \times e^{\beta_1} \times e^{\beta_1 x_{ijk}} \times \ldots \times e^{\beta_n x_{nijk}}.$$

This expression is the equation 3.2 multiplies by e^{β_1}. By rearranging the expression 3.2 we have the following equation:

$$\pi_{ijk} = \frac{e^{(\beta_0+\beta_1 x_{ijk})}}{1+e^{(\beta_0+\beta_1 x_{ijk})}} = \frac{1}{1+e^{(\beta_0+\beta_1 x_{ijk})}}. \quad (3.3)$$

Since measure of precision should always be reported with the size of the effect, 95% confidence intervals were computed using the following formula:
$e^{(\beta_1 \pm 1.96\ X\ S.E)}$, where S.E. is the standard error.

3.4.3. Multilevel ordinal logistic regression models specification

In Chapter 4 the outcome variable anaemia was recoded as mild, moderate combined with severe and not anaemic. The hierarchical structure of the data is ignored initially but then accounted for later. Model selection was performed as described above to select the significant variables that needed to be included in each final model (Omar 2003). All the final ordinal logistic models were tested for the assumption of proportionality in the odds across the response categories (parallel line). The likelihood ratio test was used with the STATA commands ***omodel*** and ***Brant*** (Brant 1990). These statistics test whether the ordinal restrictions are valid (the null hypothesis is that there is no differences in the coefficients between all the categories of anaemia). High p-values (more than 0.05) at 5% significant level are desirable. In this case there is no reasons to reject the null hypothesis (Brant 1990).

Multilevel ordinal logistic regression models are used in the analysis in Chapter 4. The outcome variable anaemia is ordered from none, mild and moderate/severe anaemia and the cut-off points used are those recommended by the World Health Organisation (WHO 1989). Anaemia has 3 ordered categories. To model the ordinal data a proportional odds model with logit link is used, where the effect of the explanatory variable x on Y is the same for all categories of the response. The model with one explanatory variable is as followed:

$$logit[P(Y_i \leq t)] = \beta_{0i}^{(t)} + \beta_1 x_i \qquad t = 1, \ldots, T-1. \quad (3.6)$$

Proportional odds model described above (3.6) can be extended to accommodate the hierarchical nature of the data. This model is a simple generalisation of the single level model. There is assumed to be a correlation between units within communities and households and women. Therefore, if it is assumed that there is clustering at two levels, say children within households and households within communities, the proportional odds model in (3.6) can be extended to allow for these random effects at household and community levels. The model for the response Y with one explanatory variable, x, is as below:

$$logit\left[P\left(Y_{ijk} \leq t\right)\right] = \beta_{0jk}^{(t)} + \beta_1 x_{jk} \qquad t = 1, \ldots, T-1, \quad (3.7)$$

$$\beta_{0jk}^{(t)} = \beta_0^{(t)} + u_{jk}^{(t)} + v_k^{(t)},$$

where $\beta_{0jk}^{(t)}$ is a random intercept for the category t in household j and community k;
β_1 is a fixed effect of x and Y across all categories and levels j and k;
$u_j^{(t)}$ and $v_k^{(t)}$ are error terms associated with category t in household j and community k and are assumed to be normally distributed $N(0, \sigma_{u0}^2)$ and $N(0, \sigma_{v0}^2)$, respectively.

Predicted cumulative probabilities

The modelling process for ordinal response involves the estimation of cumulative logit models. If it is assumed the observed response variable, Y, (anaemia), has T ordered categories (none, mild and moderate/severe), the chances that the response falls in category t or below is:

$$P(Y_i \leq t) = \pi_i^{(1)} + \cdots + \pi_i^{(t)} \qquad t = 1, \ldots., T, \quad (3.7)$$

with T the number of the response categories (T=3, not anaemic, mild and moderate).

The response probabilities for different values of x were computed to ease the interpretation of the results using the following formula:

$$\pi_t = \frac{\exp(\beta_0^{(t)}+\beta_1^{(t)}x)}{\sum_t \exp(\beta_0^{(t)}+\beta_1^{(t)}x)} \qquad \text{t=1,…T.} \quad (3.8)$$

$\beta_0^{(t)}$ and $\beta_1^{(t)}$ are the coefficients of explanatory variables. The coefficients $\beta_0^{(t)}$ and $\beta_1^{(t)}$ are zero for the reference category of each explanatory variable. Therefore we have

$$\pi_t = \frac{\exp(\beta_0^{(t)}+\beta_1^{(t)}x)}{1+\sum_{t=1}^{T-1} \exp(\beta_0^{(t)}+\beta_1^{(t)}x)}\,. \quad (3.9)$$

The probability of being in the reference category (Not anaemic) is obtained through subtraction:

$$\pi_t = 1 - \sum_{t=1}^{T-1} \pi^{(t)}. \qquad (3.10)$$

Residual analysis

For both children and women residuals were investigated twice, before and after the analysis. Before the analysis residuals were analysed to choose a suitable model for the data. For example, haemoglobin level was regressed with some explanatory variables and the residuals were plotted to see whether it was appropriate or not to use haemoglobin levels for children/women on its continuous scales, the residual plots are presented in Appendices. After a suitable model was chosen and fitted, residuals were further investigated to check whether the models assumptions such as normality, constant variance and other hold.

Multilevel ordinal and logistic regression models in this thesis were assessed to ensure that underlying assumptions such as normality are met. One assumption is that the residuals are normally distributed and have a constant variance. This was checked through the plotting of the residuals using quantile-quantile plots. If the residuals are normally distributed the plot should show a fairly straight diagonal line. The best models were selected for final interpretation of results.

For endogenous switching regression models, it is argued that the endogenous switching regression model approach relies on the joint normality of the error terms of both equations (Vytlacil and Yildiz 2007; Kim, Piger et al. 2008). The assumption of joint normality was also checked between the equations for anaemia and weight-for-age z-scores. The results for all three countries are then presented.

3.5. Summary

This chapter aimed to describe the data, define the variables and justified their categorisation, describe standard methods used in this study and provide justification for the three countries chosen for this thesis for anaemia among children and women. The chapter provides a brief description on the design of the surveys. The datasets used in this thesis are observational, retrospective cross-sectional design with complex survey design. For all three countries, the data are random representative samples drawn from probabilistic two-stage sampling design. The response rate was high in all the three countries. Multilevel logistics and ordinary logistic regression models are used and predicted probabilities are computed to ease the interpretation of the results for multilevel ordinal regression models. The choice of DRC was based on the fact that no single study has yet explored the prevalence of anaemia in this conflict zone. The Uganda 2006 DHS is the first representative data which included all regions. The few published studies which have looked at biological related factors of anaemia in Uganda and Malawi use hospital based data.

CHAPTER 4
The prevalence and Socioeconomic and demographic factors associated with anaemia in children in the Democratic Republic of Congo, Uganda and Malawi

4.1. Introduction

It was noted in the literature review that there had been little investigation into the socio-demographic factors related to childhood anaemia due to a lack of population representative data. This chapter investigates the prevalence of anaemia in children and socioeconomic and demographic factors associated with anaemia in all three countries used throughout this thesis.
This chapter aims to answer the following research questions:

(1) What is the prevalence of anaemia in the selected countries?
(2) How does the prevalence of anaemia vary within and between the three countries?
(3) What are the individual, household and community related factors associated with anaemia in children in these countries and how do they differ across the three countries?

The first step was to investigate the prevalence of anaemia in each country. The dependent variable is anaemia status (categorised as mild, moderate/severe or not anaemic). The second step investigated the simple relationships between each explanatory variable and anaemia ignoring the effects of all other variables (here anaemia was categorised as yes or not). Chi-squared test were performed to check which of the selected potential risk factors are associated with anaemia in children. Variables that were significant by at least 5% in one country were selected and included in the models. The distribution of the response variable anaemia is checked using graphical displays and numerical tests in order to identify the suitable methods for the data. Since the results suggested that haemoglobin level (anaemia) is not normally distributed and the literature suggests that the impact of anaemia on health differs depending on whether it is mild, moderate or severe, the three different levels of anaemia are modelled using ordinal logistic regression models (Riva, Tettamanti et al. 2009). The modelling assumption of parallel lines was tested. The results indicated that the model assumption was satisfied for each country. The structure of the data (children nested within women, women within households and households within communities) was accounted for by fitting multilevel ordinal logistic regression models to the data.

There are two parts to the chapter. The first part presents the prevalence of anaemia in children, the risk factors associated with anaemia in all the three countries and how the prevalence of anaemia varies by children's characteristics. The second part presents the results from the multivariable analysis on the risk factors associated with anaemia in children in each country, similarities and differences between the three countries and quantifies variations due to community and household in which children live.

4.2. The prevalence of anaemia in children

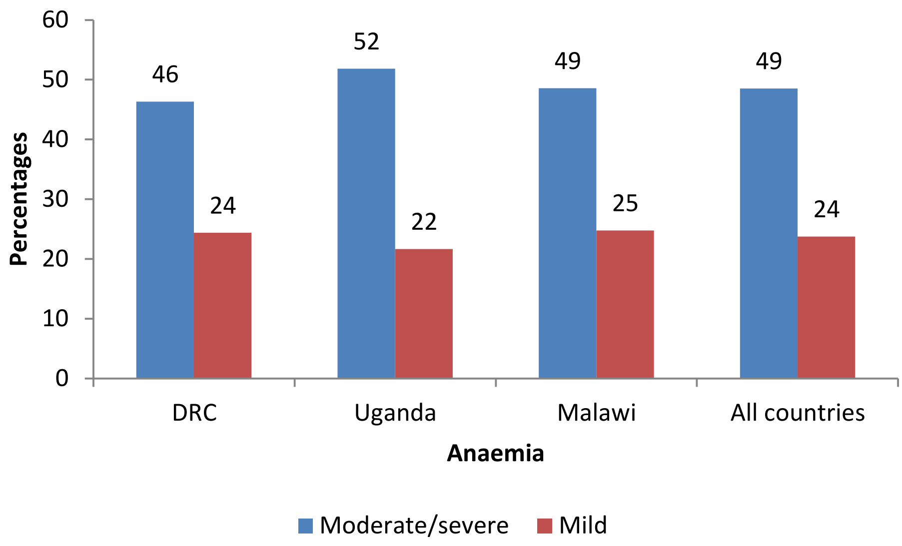
In all three countries, anaemia is highly prevalent in children aged between 6 months and 5 years old. Its prevalence is roughly the same across the three countries and ranges between 71% in DRC to 74% in Uganda. This is shown in Table 4.1 and Figure 4.1.

Table 4.1. The prevalence of anaemia in children in Uganda, Malawi and DRC

	DRC		**Uganda**		**Malawi**	
	%	n	%	n	%	n
Severe anaemia	4	140	7	142	4	116
Moderate anaemia	42	1,324	45	951	44	1,015
Mild anaemia	24	770	22	458	25	577
Total prevalence of anaemia	71	2,234	74	1,551	73	1,708
Mean haemoglobin (g/dl) 10.5			9.8		9.9	
Total sample		3,159		2,110		2,329

It is clear that the majority of children in all three countries have moderate anaemia, followed by mild anaemia, but few have severe anaemia. Also, the levels are very similar in the three countries even after combining moderate with severe categories (Figure 4.1). Mean haemoglobin is slightly higher in DRC but the same in Uganda and Malawi. Because of few observations in the severe category, moderate and severe are combined and the prevalence of anaemia is depicted in Figure 4.1.

Figure 4.1. The prevalence of anaemia in children in the DRC, Uganda and Malawi



4.3. Bivariate analysis of factors related to anaemia in children in DRC, Uganda and Malawi

This section presents the risk factors associated with anaemia in all the three countries. In this section anaemia is categorised as a binary outcome. Table 4.2 presents the potential risk factors for anaemia (yes/no) in children in all three countries. It shows that among the selected individual factors the age of the child and succeeding birth interval are common factors associated with anaemia in children in all three countries. Sex is related with anaemia in children in DRC and Uganda but not in Malawi. The weight and size of the child at birth are found to be associated with anaemia only in DRC, but not in Uganda and Malawi. However, preceding birth interval and the place of child delivery are not associated with anaemia in children in these countries.

Maternal education and household wealth status, the source of drinking water, whether the mother is anaemic and whether the child had fever are household, community, maternal, and health-related factors that are found to be related with anaemia in children in the three countries. Whether the child was ever breastfed and whether a child had diarrhoea are found to be associated with higher prevalence of anaemia in children in Uganda and Malawi but not in DRC.

Table 4.2. Risk factors associated with anaemia in children by country

Variable	DRC	Uganda	Malawi
Individual related factors			
Age	***	**	***
Sex	**	**	NS
Preceding birth interval	NS	NS	NS
Birth weight	**	NS	NS
Succeeding birth interval	**	**	**
Child size	**	NS	NS
Place of child delivery	NS	NS	NS
Household related factors			
Bed net use	NS	NS	NS
Maternal education	**	***	**
Maternal occupation	NS	*	NS
Toilet facility	NS	**	**
Wealth quintiles	***	***	***
Community related factors			
Place of residence	NS	*	*
Water source	**	**	**
Vaccination	NS	*	NS
Region	**	**	NS
Maternal related factors			
Marital status	NS	NS	NS
Smoking habit	NS	NS	**
Maternal age	NS	NS	NS
Mother anaemic	***	***	***
Nutritional related factors			
Ate vegetables in the last 7 days	NS	NS	NS
Ate meat in the last 7 days	NS	NS	NS
Whether the child was breastfed	NS	***	***
Health related factors			
Had fever in two weeks prior to the survey	***	***	***
Had diarrhoea in two weeks	NS	***	***

NS: means statistically not significant ***: p< 1% **: p< 5% *: p< 10%

The prevalence of anaemia is listed and further discussed for those variables that are statistically significant at least in one country. Table 4.3 shows the prevalence of anaemia for the individual factors that are associated with anaemia in children by country. The data indicates that in all three countries, anaemia is much more prevalent in younger children (less than two year olds) and those children who are the last births from their mothers (last birth), than it is among those aged between 2 and 5 year olds and those that are not last birth. The prevalence of anaemia also significantly differs between males and females. Anaemia is more prevalent among males than it is among females in DRC and Uganda but not in Malawi.

Table 4.3. Individual level related factors of anaemia in children by country

		DRC			Uganda			Malawi		
Variable	Category	%	n	p	%	n	p	%	n	p
Age				***			***			***
	< 2 years	79	1,210		87	827		82	1,128	
	2-5 years	68	1,949		65	1,283		66	1,201	
Sex				**			**			NS
	Female	69	1,586		71	1,063		73	1,185	
	Male	75	1,573		76	1,047		74	1,144	
Preceding birth interval				NS			NS			NS
	First births	72	586		71	295		73	466	
	<24 months	73	679		73	411		72	259	
	24-35 months	71	935		75	842		74	675	
	36+	71	959		72	562		73	929	
Birth weight				***			NS			NS
	Low	72	149		71	64		76	99	
	Normal	68	1,961		72	570		72	939	
	High	84	94		71	74		70	51	
	Not weighed at birth	78	850		74	1,351		70	1,228	
	Missing/DK	77	105		76	51		74	12	
Succeeding birth interval				**			***			***
	<24 months	65	1,779		65	1,240		67	1,340	
	24-35 months	68	566		65	464		63	12	
	36+	66	228		65	111		63	209	
	Last births	75	586		79	295		77	466	
Child size at birth				**			NS			NS
	Very large	75	535		72	169		79	201	
	Larger	69	1,122		72	591		72	561	
	Average	75	1,140		75	1,053		72	1,160	
	Small	67	356		70	297		74	270	
Total		**71**	**3,159**		**74**	**2,110**		**74**	**2,329**	

NA: Not applicable, % :percentages; n: number of observations; p:Chi-Square P-value ***: p< 1% **: p< 5% *: p< 10%

As indicated in Table 4.2, maternal level of education and wealth quintiles are common household factors that are significantly related to anaemia in children in all three countries (see also Table 4.4). The prevalence of anaemia tends to decrease with increasing levels of maternal education in Uganda and Malawi. Anaemia is much more prevalent among children of mothers without education and lower among children of those mothers with at least a secondary education (see Figure 4.2). Education is linked with other socioeconomic factors such as wealth status, better nutrition, diet and affordability. A lower prevalence observed among children of educated mothers could be because of the access to information and the ability to process it which improves knowledge about the choice of food or it could be due to a spurious relationship as a result of other unseen factors such as poverty (Panis and Lillard 1994). Household wealth status is another important factor associated with anaemia in children in these countries. The data suggest that the prevalence of anaemia decreases with an increased wealth status. It is higher among children from poor households and lower among those children from richer households (see Figure 4.3).

Table 4.4. Household factors of anaemia in children

		DRC			Uganda			Malawi		
Variable	Category	%	n	p	%	n	p	%	n	p
Maternal education				***			**			***
	None	70	736		76	502		74	597	
	Primary	76	1,404		74	1,333		74	1,501	
	Secondary	67	1,019		67	275		65	231	
Maternal occupation				NS			***			NS
	Not working	74	782		74	152		72	884	
	Prof & management	78	61		55	45		68	19	
	Clerical & sales	29	29		63	169		74	234	
	Agriculture	72	1,622		75	1,571		74	1,130	
	Services/ manual	69	69		81	164		31	50	
	Domestics	NA	NA		71	9		88	12	
Toilet facility				NS			***			***
	Flush	70	128		31	14		58	37	
	Pit/bucket	72	2,578		71	1,362		72	1,300	
	None	72	453		78	734		84	392	
Wealth status				**			***			***
	Poorest	71	713		80	500		79	441	
	Poorer	79	600		75	451		77	541	
	Middle	75	651		73	443		73	585	
	Richer	66	675		74	371		72	493	
	Richest	68	520		61	345		64	269	
Total sample (N)		**71**	**3,159**		**74**	**2,110**		**74**	**2,329**	

NA: Not applicable, % :percentages; n: number of observations; p:Chi-Square P-value ***: p< 1% **: p< 5% *: p< 10%

Figure 4.2. The prevalence of anaemia by mother's level of education and by country

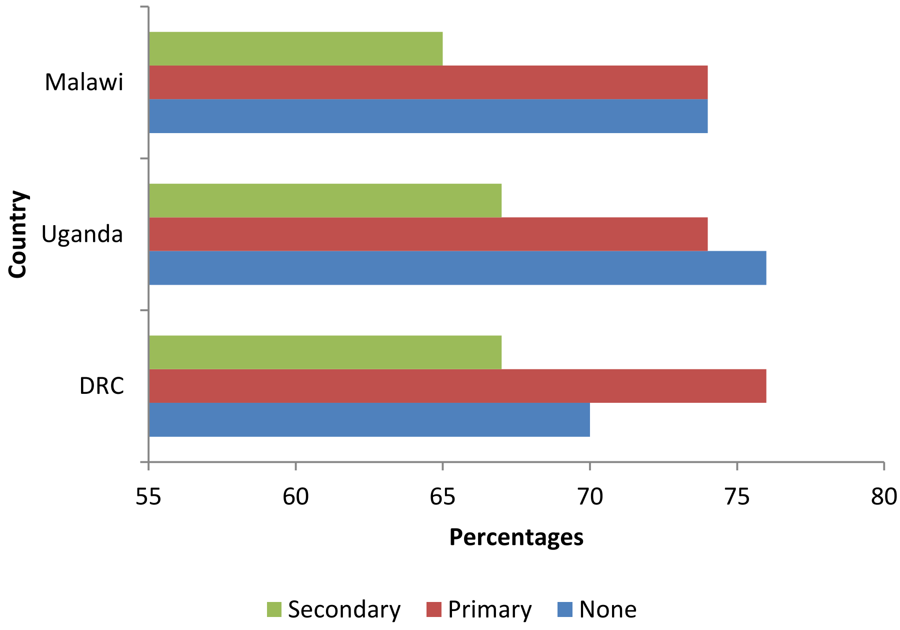
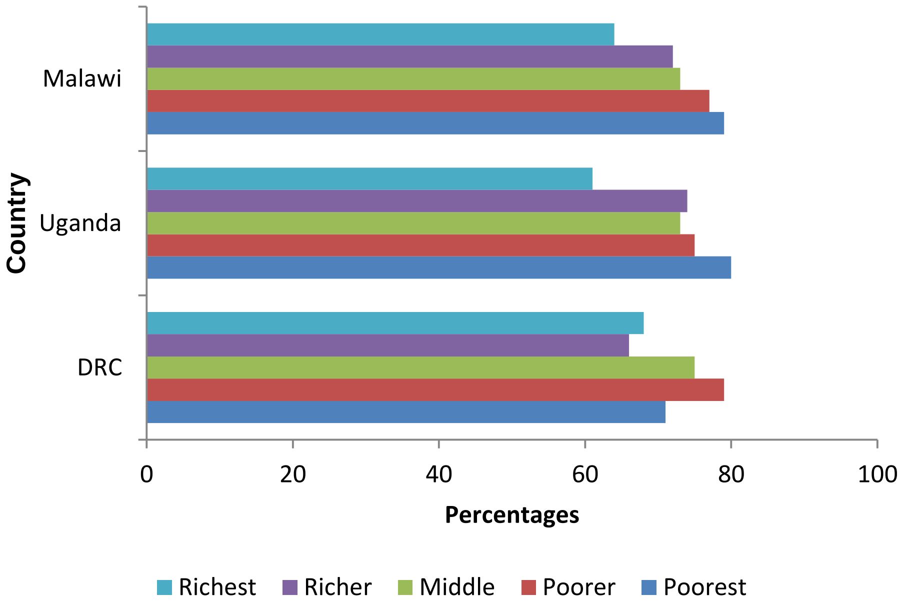


Figure 4.3: The prevalence of anaemia in children by household wealth status and by country



The source of drinking water is a community factor that is found to be associated with anaemia in children in all three countries. Compared to children who use piped water as the main source of drinking water, anaemia is more prevalent among those children who drink from other sources (see Table 4.5). The region of residence is another community related factor that is found to be related with anaemia in children. In Uganda the prevalence of anaemia is lower in children from Kampala (the capital city) than it is in other regions. However, in DRC children from Kinshasa, the capital city, are associated with a higher prevalence of anaemia compared to other regions. These results are not surprising for Kinshasa and can be justified by many factors including rural-urban migration which has continued at a rapid pace (Potts 2000; Beauchemin and Bocquier 2004). In developing countries in general, subsistence farmers form the bulk of rural poor. Since they cannot sustain themselves and their families on the small parcels of land they own or cultivate, some of them migrate to towns or cities on either a temporary or a long-term basis in the hope of enhancing their quality of life. Many adults are living in towns but are not working. It is argued that hundreds millions of urban dwellers in developing countries are exposed to undernutrition today because of the lack of income and their health and nutritional status are at risk from any staple food price rise (Satterthwaite, McGranahan et al. 2010). Rural-urban migration in DRC is exacerbated by individuals fleeing for internal rebellions or other forms of political persecution in regions. By far the greatest majority of these displaced people are rural farmers or herdsmen who have been caught up in the ravages of internal rebellions (Emizet 2000). This could partially justify a higher prevalence of anaemia found in children in Kinshasa, the capital city of DRC.

Anaemia is much more prevalent in children of anaemic mothers and children who had fever or diarrhoea than it is among those whose mothers are not anaemic or amongst children who did not have fever or diarrhoea (see Table 4.5). A higher prevalence found among children who had fever could be due to the association between fever and malaria. Previous research has suggested that anaemia is highly prevalent in areas where malaria is endemic. In some studies, fever has been used as a proxy for malaria (Meremikwu, Logan et al. 2000).

Table 4.5. Percentages of children with anaemia by country for community, maternal, nutritional, and health related factors

		DRC			Uganda			Malawi		
Variable	**Category**	**%**	**n**	**P**	**%**	**n**	**P**	**%**	**n**	**P**
Community factors										
Place of residence				NS			***			**
	Rural	73	1,873		75	1,893		74	2,120	
	Urban	71	1,286		58	217		67	209	
Water source				**			***			***
	Other	72	2,920		74	2,060		74	2,260	
	Piped	65	239		45	50		53	69	
Region				***			***			NS
Maternal factors										
Smoking habit							NS			*
	No	72	3,096		73	1,990		73	2,295	
	Yes	56	63		73	120		87	34	
Mother anaemic				***			***			***
	No	65	1,546		67	1,024		69	1,200	
	Yes	78	1,573		79	1,071		79	910	
Nutritional and health										
Vaccination				NS			**			NS
	Not	75	407		78	115		68	115	
	Yes	72	2,082		68	829		71	656	
Breastfeed				NS			***			***
	No	69	1,142		63	737		67	1,448	
	Yes	73	2,017		79	1,373		76	877	
Had fever				**			***			***
	No	69	2,116		67	1,163		69	1,816	
	Yes	77	1,011		81	943		81	877	
	DK	64	320		100	4		67	4	
Had diarrhoea				NS			***			***
	No	72	2,618		71	1,519		72	1,816	
	yes	71	517		80	587		80	512	
	DK	78	24		65	4				
Total (N)		**71**	***3,159***		**74**	***2,110***		74	***2,329***	

n: number of observations; p:Chi-Square P-value ***: p< 1% **: p< 5% *: p< 10%

The association found between anaemia and some of the socioeconomic and demographic factors as suggested in this section might be spurious. Hence the next section will control the effects of multiple factors while estimating the effect of each individual factor.

4.4. Multilevel ordinal regression analysis of risk factors associated with anaemia in children in DRC, Uganda and Malawi

Based on the distribution of the outcome variable (haemoglobin level) and the hierarchical nature of the data as described in Chapter 3, multilevel ordinal regression models were fitted to the data. Odds ratios and their associated 95% confidence intervals were also computed (see Appendix 4.1). However, predicted probabilities are used to facilitate the interpretation of the results. To enable comparisons to be made across countries, a standard set of control variables are included in the analysis as presented in Table 4.6. Four models are estimated, one model for each of the three countries separately and one model for all three countries together including a cross-country variable. Only variables that were at least significant in one country were included in the model for the three countries combined.

Categories of the outcome variable anaemia, ordered from not anaemic, mild, moderate/severe are reduced into three categories. Severe was combined with moderate anaemia due to few observations for severe anaemia in all three countries. Not anaemic is considered as the reference category in all models.

4.4.1. Determinants of mild to moderate anaemia in children in DRC, Uganda and Malawi

Table 4.6 presents the determinants of anaemia in children in the three countries. After controlling for the effects of all the selected factors it is seen that the age, sex and birthweight, household wealth status, source of drinking water, region, whether the mother is anaemic and whether the child had fever are risk factors associated with anaemia in children at least in one of the three countries. However, the association that was previously found between anaemia and factors such as maternal level of education, bed net use and breastfeeding was not significant any more after controlling for the effect of other observed factors such as drinking water and household wealth status (see Table 4.6). The study also suggests that the age of the child, and whether the mother is anaemic are common factors that are associated with the children's risk of having anaemia in all three countries. Beside these factors, sex and region are among other factors associated with anaemia in children in DRC and Uganda but not in Malawi. The source of drinking water is related to anaemia in children in Uganda and Malawi but not in DRC. Furthermore, whether children had a fever two weeks prior to the interview is found to be related with the risk of having anaemia in Malawi but not in DRC and Uganda (Table 4.6).

Table 4.6. Risk factors associated with mild to moderate anaemia in children by country.

Variable	DRC	Uganda	Malawi
Individual related factors			
Age	***	***	***
Sex	***	**	NS
Birth weight	**	NS	NS
Household related factors			
Bed net use	NS	NS	NS
Maternal education	NS	NS	NS
Wealth quintiles	NS	NS	*
Community related factors			
Water source	NS	**	***
Region	**	***	NS
Maternal related factors			
Mother anaemic	***	***	***
Nutritional related factors			
Breastfeed	NS	NS	NS
Health related factors			
Had fever	NS	NS	**

NS: means statistically not significant ; ***: p< 1% **: p< 5% *: p< 10%

Predicted probabilities were computed for factors that are associated with children's risk of having anaemia at least in two countries to estimate children's likelihood of having mild or moderate anaemia and to see how it varies by group, such as sex, age maternal anaemia status, source of drinking water and also by country (Table 4.7).

Table 4.7 Predicted probabilities of mild to moderate anaemia in children from DRC, Uganda and Malawi

		DRC			Uganda			Malawi			All countries		
Variable	Categories	Not Anaemic	Mild	Moderate	Not Anaemic	Mild	Moderate	Not Anaemic	Mild	Moderate	Not Anaemic	Mild	Moderate
Individual probabilities		0.28	0.25	0.48	0.33	0.16	0.51	0.28	0.23	0.49	0.29	0.22	0.49
Age													
	<2 years(Ref)	0.28	0.25	0.48	0.33	0.16	0.51	0.28	0.23	0.49	0.29	0.22	0.49
	2-5 years	0.35	0.19	0.46	0.43	0.11	0.46	0.30	0.21	0.48	0.35	0.18	0.47
Sex													
	Female(Ref)	0.28	0.25	0.48	0.33	0.16	0.51	0.28	0.23	0.49	0.29	0.22	0.49
	Male	0.25	0.28	0.48	0.30	0.18	0.52	0.27	0.24	0.49	0.27	0.24	0.49
Mother's anaemia status													
	Not anaemic (Ref)	0.28	0.25	0.48	0.33	0.16	0.51	0.28	0.23	0.49	0.29	0.22	0.49
	Anaemic	0.24	0.28	0.48	0.29	0.19	0.53	0.24	0.27	0.49	0.25	0.26	0.49
Drinking water source													
	Others(Ref)	0.28	0.25	0.48	0.33	0.16	0.51	0.28	0.23	0.49	0.29	0.22	0.49
	Piped	0.29	0.24	0.47	0.43	0.07	0.51	0.34	0.18	0.47	0.31	0.21	0.48
Country													
	DRC(Ref)										0.29	0.22	0.49
	Uganda										0.32	0.20	0.48
	Malawi										0.28	0.23	0.49

Figure 4.4. Predicted probabilities of mild to moderate anaemia in children by country

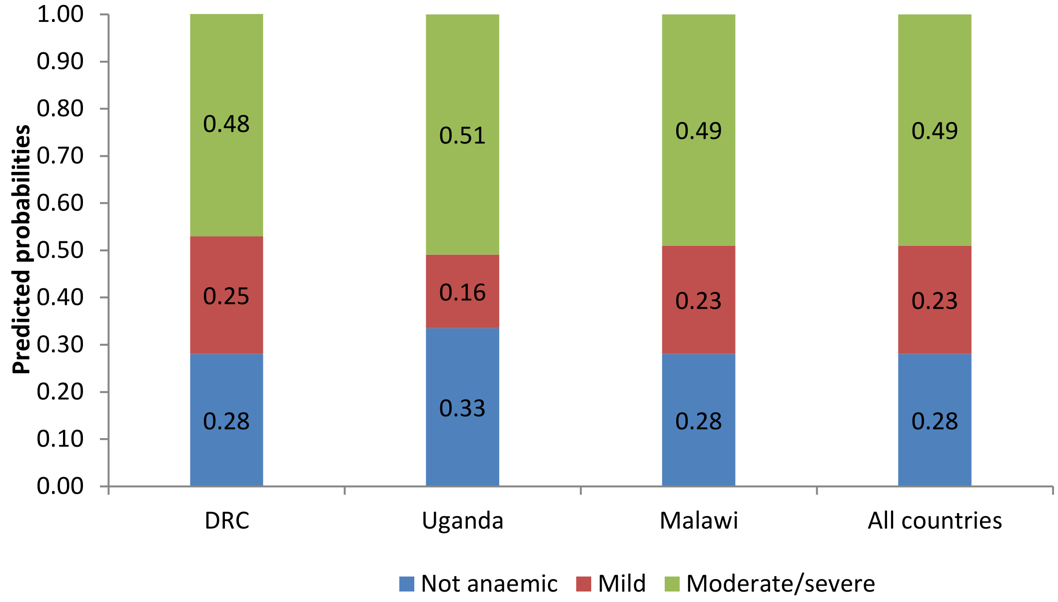
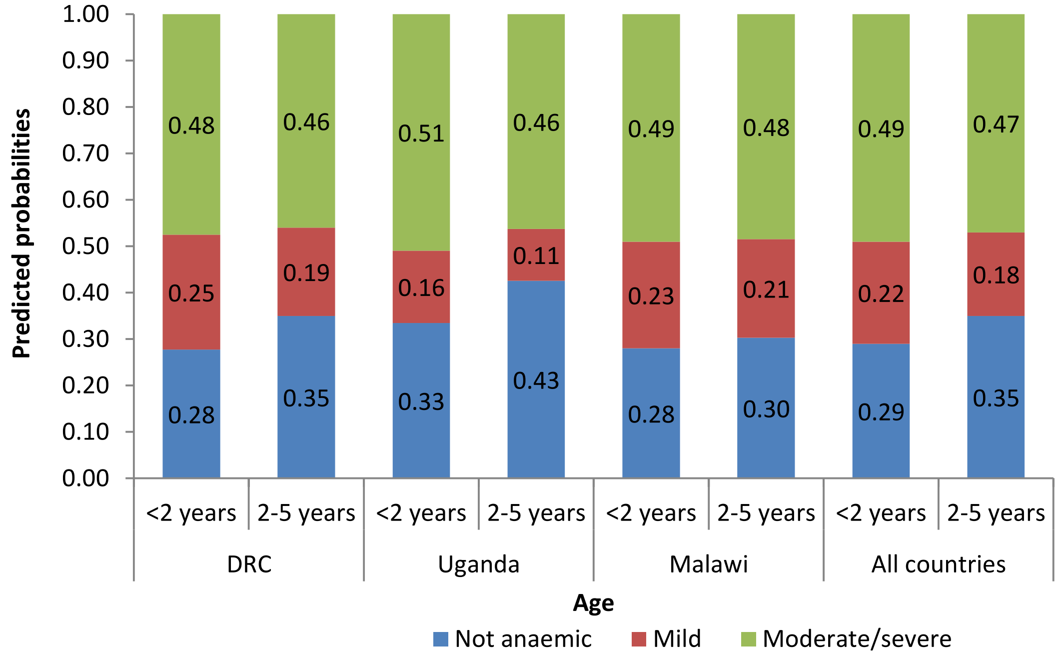


Figure 4.4. presents the predicted probabilities for mild to moderate anaemia in children in the *reference category (e.g. females or aged less than two years or whose mothers are not anaemic)* for each country. In all the three countries, the children's chance of having moderate/severe anaemia is roughly the same. Children are twice more likely to have moderate/severe anaemia than being mildly anaemic. The results also suggest that those children from Uganda are less likely to have mild anaemia but are more likely to have moderate/severe anaemia compared with those from DRC and Malawi if in the reference category. The results from the general model are similar to those from Malawi even for other individual variables in the model.

4.4.2. Similarities between countries

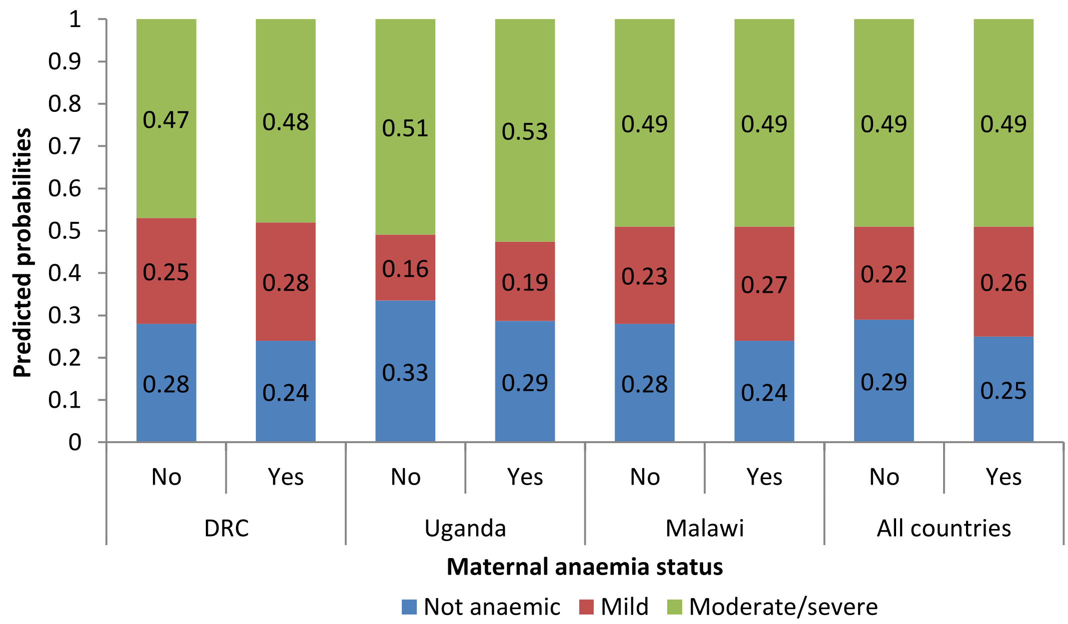
Age is a common factor associated with the risk of mild to moderate anaemia in all the countries even after controlling for all the other observed potential risk factors. In DRC and Uganda, compared with those children aged between two and five years old, younger children are more likely to have mild and moderate/severe anaemia, as depicted in Figure 4.5.

Figure 4.5. Predicted probabilities for anaemia in children by age and by country



Maternal anaemia status is the only maternal related factor that is found to be associated with an increased chance of anaemia in children in all the three countries. Compared with those children whose mothers are not anaemic, children of anaemic mothers are more likely to have mild anaemia than being not anaemic as presented in Figure 4.6.

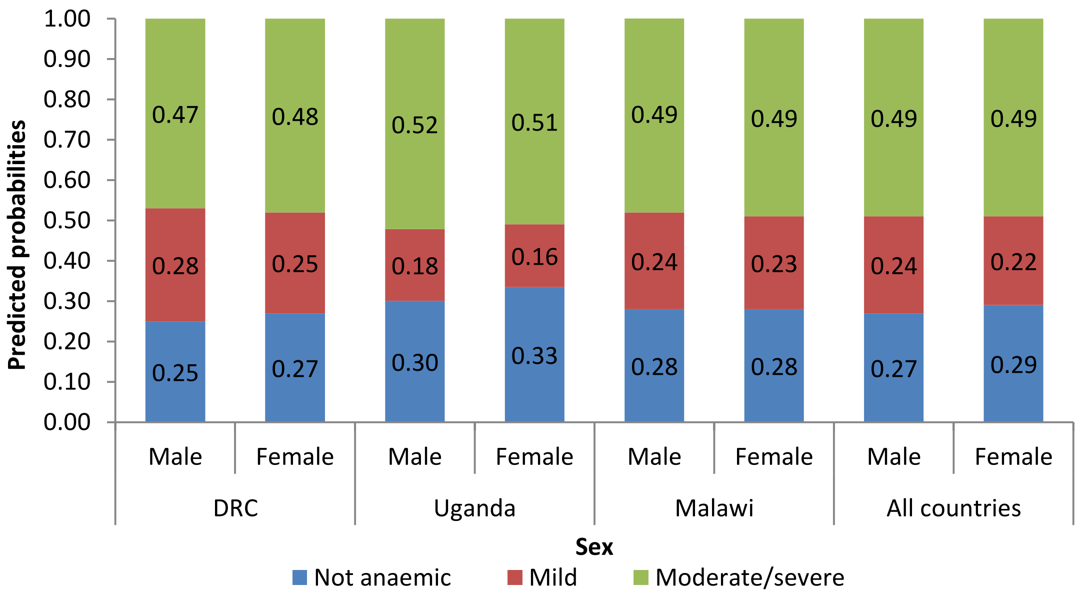
Figure 4.6. Predicted probabilities of anaemia in children by maternal anaemia status and by country



4.4.3. Differences between countries

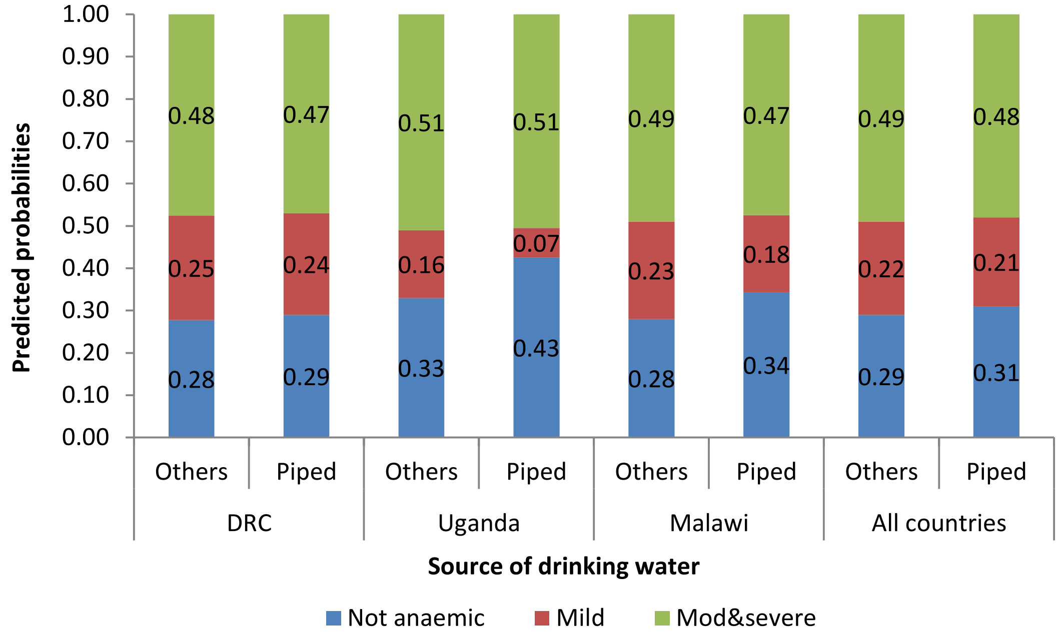
Sex is significantly associated with anaemia in children in DRC and in Uganda. In these two countries male children are more likely to have moderate/severe anaemia and mild anaemia compared to females. However, there is no difference in the probabilities of anaemia between males and females in Malawi and in the combined model, as seen in Figure 4.7.

Figure 4.7. Predicted probabilities of anaemia in children by sex and by country



The source of drinking water is among other factors associated with anaemia in children in Uganda and Malawi. In both countries, children from households who had other sources of drinking water were found to have an increased chance of having anaemia than children from households that have piped drinking water. This difference was significant in Uganda and Malawi, but not in DRC and when all data are together (Figure 4.8).

Figure 4.8 Predicted probabilities of anaemia in children by the source of drinking water and by country



Whether the child had fever in the last two weeks is found to be related with an increased chance of being anaemic in Malawi. Children who had fever are more likely to have mild anaemia compared with their counterparts who had no fever. This difference was not statistically significant in Uganda and DRC. In addition, the results suggest that although there are differences between countries the difference is not statistically significant ($p>0.05$).

4.4.4. Unexplained variability in the risk of having anaemia within the selected countries

The hierarchical nature of the data was accounted for through the use of multilevel models in order to account for unexplained variability in children's risk of having anaemia. Variance components and their associated standard errors were obtained where possible for each level (community or household) to explain variability in children's risk of having anaemia which is due to community or household effects. Simple t-tests were carried out by dividing the variance components with its associated standard error (Paternoster, Brame et al. 1998). Table 4.8 display the variance components for each country. The results suggest that there are significant variations between communities in DRC in the children's risk of having anaemia. In other words, besides individual child characteristics, children's risk of having anaemia in DRC is significantly influenced by unknown/ unmeasured community factors. These can include behavioural factors such as dietary intake, sociocultural norms such as food taboos and cultural beliefs that certain food should not be eaten for cultural reasons (Bhandari, Bahl et al. 2001; Lock, Pomerleau et al. 2005). However, no significant differences were found between communities or households in Uganda and Malawi. Since household's effects were not significant in all three countries, random effects at household level were removed from the models and are not presented.

Table 4.8.Variance components and standard errors for community level variations by country

Level	DRC Variance	SE	Uganda Variance	SE	Malawi Variance	SE
Community	0.148	0.043	0.081	0.049	0.027	0.082

4.5. Discussion

The aims of this chapter were to investigate the prevalence of anaemia among children and socioeconomic and demographic risk factors associated with anaemia in children in DRC, Uganda and Malawi. The chapter also aimed to investigate whether besides the observed characteristics there are unobserved household and community variations in children's risk of having anaemia in these three countries.

This chapter contributes to research on the prevalence and socioeconomic and demographic factors associated with anaemia (mild or moderate/severe) among children in DRC, Uganda and Malawi. Multilevel ordinal regression models have highlighted specific socioeconomic and demographic risk factors associated with anaemia among children from DRC, Uganda and Malawi. In particular, the results have shown that age, sex, maternal anaemic status, the source of drinking water, fever and region are strongly associated with anaemia among children at least in one of the three countries. However, the relationship which was suggested in univarate analysis between anaemia and factors such as maternal education, bed net used, breastfeeding, household wealth status and place of residence is not significant anymore after accounting for the effects of factors such as the source of drinking water, age, sex and unobserved community factors.

With regards to age, younger children (<2 years old) are more likely to be anaemic (moderate or mild) compared with those children aged between 2 and 5 years old. Although infants can form antibodies from birth, their antibodies could still be weak below the age of 2 years (Olusanya, Luxon et al. 2004). The results are also in line with a study which suggested that the peak prevalence of iron deficiency occurs around 18 months of age after that iron requirements decline (Karen 2003). The other factors which might expose younger children to anaemia are the lack of proper dietary food and lack of child health knowledge. Similar results were found in studies looking at risk factors associated with other anaemia-related illnesses such as malaria and diarrhoea (Jamison and Mosley 1991; Clegg and Weatherall 1999; Demir, Yarali et al. 2002).

Maternal anaemia status is an important risk factor of anaemia among children. Children of anaemic mothers are more likely to have any anaemia. The importance of maternal health on children health and wellbeing has been documented elsewhere (Kahn, Wise et al. 1999). It is argued that maternal malnutrition could decrease the concentration of some micronutrients such as vitamin A, iodine in breast milk and, therefore, increase the risk of infant depletion (Karen 2003).

The source of drinking water is among many other important risk factors associated with anaemia among children. Although diarrhoea is not found to be directly related with anaemia in children in this chapter, other studies argue that unclean water is directly linked with diarrhoea and hookworms which in turn are directly linked with anaemia and that diarrhoea during infancy is associated with malabsorption of nutrients such as iron and vitamins (Karen 2003; Riley, Ko et al. 2007). No significant differences found in the risk of anaemia between children who drink from pipe and other sources are unexpected in this conflict zone, DRC. Although DRC is the basin of most of perennial rivers, access and supply of safe water to the population is still a major concern due to social and political conditions such as repeated conflicts (Ashton 2002; Obi, Onabolu et al. 2006). By region, this chapter suggests that there are significant regional differences in children's risk of anaemia in DRC and Uganda. These differences could be attributed to environmental, climatic and economic conditions, which are important not only for food production but also distribution. With regards to cross-country differences observed in children's risk of anaemia, the country variable suggest that the differences observed are not statistically significant.

The association found between anaemia and fever is not unexpected. Although every fever is not merely due to malaria, fever has been use as a proxy for malaria. Malaria is argued to be strongly related with anaemia (Halliday, Karanja et al. 2012). Malaria infection destroy red blood cell and reduce haemoglobin levels leading to anaemia (Menendez, Fleming et al. 2000). Clinical studies argue that the key feature of the biology of malaria infection (plasmodium falciparum) is its ability not only to destroy red blood cells but also to cause the infected red blood cell to adhere to the linings of small blood vessels (Huynh, Fievet et al. 2011; Rebollo, Perez et al. 2011; Phiri, Esan et al. 2012; Valea, Tinto et al. 2012). Another pathogenesis of malaria infection is that it involved in compromising blood flow through tissues and this is one of the reasons that individuals affected with malaria often become dehydrated, hypovolaemic and have reduced oxygen delivery to tissues (Miller, Baruch et al. 2002).

Large and significant community-level random effects for DRC show that children's risk of anaemia greatly varies between communities. The inclusion of the existing explanatory variables does not fully capture all the determinants of anaemia among children. This may signify the omission of factors on anaemia occurrence that may have been difficult to measure, were not thought about, were unobservable or were less quantifiable but nevertheless cumulative. Examples include the presence of ailments such as malaria, unobservable and less quantifiable malnutrition, and social, behavioural, cultural believes (food taboos), spatial and other environmental factors.

With comparison to the few studies which explored social risk factors of anaemia among children, this chapter has contributed to understand Socioeconomic and demographic factors associated with mild, moderate and severe anaemia among children. In the study by Ngie-Teta (2007), the only study which has looked at the social aspect of anaemia, the effect or mild anaemia was ignored. Although clinical literature suggests that even mild anaemia can impair cognitive development of children, mild anaemia was combined with not anaemic. In addition, this chapter has included maternal anaemia status to predict children's risk of anaemia. This was not done in previous studies. This chapter has suggested that if the mother is diagnosed with anaemia, her children might be at higher risk of having anaemia.

4.6. Summary

This chapter aimed to describe the prevalence of anaemia in children in the selected countries, explore the risk factors associated with mild and moderate/severe anaemia in children and quantify where possible the effects of communities and households factors. This study found that anaemia is highly prevalent in the three countries and its prevalence is roughly the same. The high prevalence of anaemia among the studied children should be given serious consideration.

The results also suggest that for all three countries the age of the child, maternal anaemic status and household wealth are common risk factors that expose children to the risk of mild or moderate/severe anaemia. Besides these common risk factors and other unknown factors that are related to anaemia in children, sex of the child and region were found to be significantly related to anaemia in children in the DRC.
In addition, the source of drinking water is also among many other anaemia-related factors in children in Uganda and Malawi. Whether the child had fever or not is found to be associated with anaemia in children only in Malawi but not in DRC and Uganda.

Random effect models suggested that anaemia in children varies significantly only within communities in DRC. However, there is no significant difference between community and household in Uganda and Malawi. The challenge then is to identify communities in the high risk groups and implement preventive measures. Further investigations are needed in order to improve the health of younger male children and prevent anaemia in children from households where mothers are anaemic.

CHAPTER 5
Children's Nutritional Status and Anaemia

5.1. Introduction

Child health outcomes are the result of many factors including genetic, biological, behavioural, socioeconomic, and environmental causes. In the past, the determinants of health in general and child health in particular were investigated separately for biological, socioeconomic or behavioural causes. Several researchers, however, initiated the use of a framework in which proximate biological and their underlying socioeconomic and behavioural factors are integrated into a single conceptual model (Kooiman 1984; Mare 1985; Lozoff, Jimenez et al. 2000; Griffin and Abrams 2001). Many potential explanatory factors in these frameworks are interrelated and as a result the integration of all factors into a single model is not without its problems (Robert 2000). These problems include the fact that as the model gets more complex, some explanatory variables in one equation are then dependent variables in another, with both equations being part of the same model. If appropriate methods are not used, one might end up with endogeneity bias, misclassification and confounding (Lozoff, Jimenez et al. 2000).

Anaemia and other indicators of nutritional status are influenced by many of the same factors, including dietary intake and many others which might be unobservable to the researchers. Dietary intake is a behaviour, which is modifiable by the individual in response to their nutritional status (Robert 2000). Therefore, neither anaemia nor child nutritional status can be evaluated without considering the unmeasured variables such as dietary intake. The other problem is that ignoring these issues (e.g. endogeneity) leads to erroneous estimates of the impact of individual variables within the model and erroneous conclusions (Briscoe, Akin et al. 1990; Lozoff, Jimenez et al. 2000). Furthermore, failure to use endogenous switching model may result in the effects of individual variables estimated using standard Ordinary Least Square regression models being inconsistent and biased. The effect of some individual variables could be underestimated while the effects of other variables are overestimated or in the opposite direction.

5.2. Endogeneity bias

The definition of the term 'endogenous', as sometimes used in biology, describes something that originates inside a system or the body. When something originates outside the system, it is said to be exogenous. Both endogenous and exogenous are also used in an analogous ways in some branches of statistics, epidemiology and health economics. In the context of regression models, a variable that is referred to as endogenous is one whose value is at least partially determined by the value of other variables within the model. For example, a dependant variable "Y" in a regression equation is said to be endogenous if it is modelled as a function of the set of explanatory variables "X, T and Z". Yet, the variable "T" could also be endogenous, if its value is influenced by any of the other explanatory variables correlated with the error term or even influenced by the dependent variable "Y". Failure to consider these relationships can lead to endogeneity bias, the statistical bias that arises when an endogenous variable is treated as exogenous (Chantry, Howard et al. 2007).

5.3. The biases when endogeneity is ignored

There are few epidemiological studies that illustrate the biases when endogeneity is not taken into account. Briscoe et al. (1990) uses health and health-related behaviour to illustrate biases when endogeneity is ignored. To begin with, the paper suppose that there exists a true relationship between a biological factor ('a baby is less likely to become ill if it is breastfed') and behavioural factors such as the culture (where the culture is one that promotes breastfeeding of young children). Breastfeeding not only affects health, but it is also the result of the 'perceived health of the child'. The paper uses graphical tools to illustrate how ignoring endogeneity between breastfeeding and health (the fact that behaviour affect health and health affects behaviour), not only biases the measures of behaviour on health, but also biases the estimates of other individual variables in the model. The study shows that the estimated effect of breastfeeding on health is substantially different from the true relationship (Briscoe, Akin et al. 1990).

Another study is by Schultz (1984) which investigated the effect of prenatal care on infant mortality in the United States. The study examined how mothers-to-be make decisions on the level of prenatal care to be sought, showing that this decision is affected by the 'health endowment' of the foetus (which is unobservable to a researcher). The paper emphasises the relationship between biological and behavioural factors by suggesting that 'when a woman has either had a problematic pregnancy before or has difficulties with the current pregnancy, she is more likely to seek early prenatal care'. Yet the decision for seeking early prenatal care is behaviour and is related to both 'the prenatal care to be sought' and 'health endowment, child mortality'. The paper came to a conclusion that if endogeneity between prenatal care and child mortality is not taken into account, either: the beneficial effect of prenatal care on child mortality would be underestimated or prenatal care would appear to have adverse effects on child health (i.e. the estimated $\beta_{estimate}$ could be positive when the true estimate β_{true} is negative). When prenatal care was treated as an exogenous variable, the effect of prenatal care increased infant mortality. However, when prenatal care was treated as endogenous, prenatal care was found to reduce the effect of infant mortality (Schultz 1984).

5.4. Correcting for endogeneity

From the earlier discussion it should be apparent that the important task is to separate the correlation between the explanatory variable and the error term. The error term consists of two parts, the error term from observed and unobserved factors. There are standard statistical techniques for correcting for the effect of endogenous explanatory variables. These include the use of instrumental variables and endogenous switching regression methods. An instrumental variable is a proxy explanatory variable (often obtained at great effort) which is correlated with the endogenous variable but not with the error term. If a valid instrumental variable exists it can simply be substituted in place of the known, true value of the endogenous variable, and thus the estimate could be unbiased. The problem with this technique is not only to obtain a valid instrumental variable but also it might be empirically difficult to disentangle the direct effect of the endogenous regressor and the outcome variable from the effect exerted on the latter variable through the correlation of the error terms (Rogerson, Aitken et al. 2007).

Another method of correcting for endogeneity bias is to use endogenous switching regression models. Endogenous switching regression models can be estimated with the two-step estimation method or with the Full Information Maximum Likelihood estimation (FIML). It is argued that FIML estimators are most efficient among estimators of the simultaneous regression model which is the endogenous switching regression model in this case. FIML considers the entire system of equations and all the parameters are jointly estimated (Garcia-Casal, Leets et al. 2008). The most important aspect of FIML estimators that give them an advantage over other estimators is that the estimators obtained by FIML share the same properties of maximum likelihood estimators. They are consistent and asymptotically normally distributed (Garcia-Casal, Leets et al. 2008).

Children's growth measurements such as weight, height and age converted into standard deviations (z-scores) are often used to reflect children nutritional status. Weight-for-age z-scores is often used as a proxy for both long and short term malnutrition, height-for-age z-scores as a proxy for long term malnutrition and height-for-weight z-scores as a proxy for short term malnutrition (De Onis and Blössner 2003; Rahman, Iqbal et al. 2004). The advantage in using weight-for-age z-scores is that it can capture both long and short term malnutrition.

This chapter investigates the link between children's nutritional status (weight-for-age z-scores) and anaemia. It aims to answer the following research questions:

(1) Is anaemia endogenous to weight-for-age z-scores?
(2) What is the effect of ignoring endogeneity between anaemia and weight-for-age z-scores?
(3) What are possible common observed/unobserved factors that might influence anaemia during childhood and weight-for-age z-scores?

A correlation between unobserved covariates that might influence both anaemia and weight-for-age z-scores was tested to check whether endogeneity exists in order to use the appropriate model. The results indicated that anaemia is endogenous to weight-for-age z-scores. Endogenous switching regression models were fitted to the data. The extension of the literature in this study is that both anaemia and weight-for-age z-scores are treated as outcomes and are simultaneously modelled.

The joint estimation procedure allows anaemia to be treated as endogenous to weight-for-age z-scores. The use of endogenous switching regression models provides two benefits: first, the estimation procedure allows the variable anaemia to be treated as endogenous to weight-for-age z-scores and eliminates the inconsistency that may arise from ignoring endogeneity. Finally, it controls for unobserved factors and eliminates potential omitted variable bias (Briscoe, Akin et al. 1990).

5.5. Endogenous switching regression model specification

The underlying continuous latent for anaemia is defined as $\boldsymbol{I}_i^*$ and the continuous variable weight-for-age z-scores as y_i. The sample observed consists of anaemic and not anaemic children where $I_i = 1$ if the child is anaemic and $I_i = 0$ if the child is not anaemic:

$I_i = 0$ if $I_i^* < 0$ and

$I_i = 1$ if $I_i^* > 0$.

The observed weight-for-age z-scores,

$y_i = y_{1i}$ if $I_i = 1$, for anaemic children (1).

$y_i = y_{2i}$ if $I_i = 0$, for not anaemic children (2).

The basic switching regression model with endogenous switching is defined as the following system of equations:

$y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i}$ (3)

$y_{2i} = X_{2i}\beta_2 + \varepsilon_{2i}$ (4)

$I_i^* = Z_i\gamma - \varepsilon_{3i}$ (5)

Here Z_i is an exogenous row vector and γ is a vector of parameters.

Also $(\varepsilon_{1i}, \varepsilon_{21}, \varepsilon_i) \sim N_3(0, \Sigma)$ are independent where Σ is the positive defined matrix

$$\Sigma = \begin{bmatrix} \varepsilon_{11} & \varepsilon_{12} & \varepsilon_{1\eta} \\ \varepsilon_{12} & \varepsilon_{22} & \varepsilon_{2\eta} \\ \varepsilon_{1\eta} & \varepsilon_{2\eta} & 1 \end{bmatrix} \quad (6)$$

.

This approach relies on joint normality of the error terms in the latent and continuous equations $(\varepsilon_{1i}, \varepsilon_{2i}, \varepsilon_{3i})$. If we decompose the error terms $\varepsilon_{1i}, \varepsilon_{2i}$ *and* ε_{3i} into a set of correlated and noncorrelated components, we can rewrite the equations (3), (4) and (5) as followed:

$y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i}^* + \omega_{1i}$ (7)

$y_{2i} = X_{2i}\beta_2 + \varepsilon_{2i}^* + \omega_{2i}$ (8)

$I_i^* = Z_{\mathrm{i}}\gamma + \varepsilon_{3i}^* + \omega_{3i}$ (9)

where $w_i' = (w_{1i}, w_{2i}, w_{3i}) \sim N(0, \Omega)$ and $\varepsilon_i' = (\varepsilon_{1i}^*, \varepsilon_{2i}^*, \varepsilon_{3i}^*) \sim N(0, \Lambda)$; w_i' are independent of ε_i'; and Ω and Λ are the following matrices:

$$\Omega = \begin{bmatrix} \omega_{11} & 0 & 0 \\ 0 & \omega_{22} & 0 \\ 0 & 0 & \omega_{33} \end{bmatrix}$$

and $\Lambda = \begin{bmatrix} \lambda_{11} & \lambda_{12} & \lambda_{13} \\ \lambda_{12} & \lambda_{22} & \lambda_{23} \\ \lambda_{13} & \lambda_{23} & \lambda_{33} \end{bmatrix}$.

This is the same method with the one in equations (3) and (5), where

$\lambda_{11} = \omega_{11} = \varepsilon_{11}$; $\lambda_{22} = \omega_{22} = \varepsilon_{22}$; $\lambda_{33} = \omega_{33} = 1$; $\lambda_{12} = \varepsilon_{12}$; $\lambda_{13} = \varepsilon_{1\eta}$ and $\lambda_{23} = \varepsilon_{2\eta}$.

It is apparent that the models (7) to (9) and (3) to (5) are not different models (Maddala 1993).

5.6. Testing for endogeneity

Let both ρ_1 and ρ_2 denote correlation coefficients as follows:

ρ_1 is the correlation coefficient for the observed and unobserved factors between equations (3) and (5) for anaemic children and ρ_2 the correlation coefficient for observed and unobserved factors between equations (4) and (5) for children who are not anaemic.

The model presented by (3)-(5) together with the data in equations (1) and (2) are said to be endogenous switching if ρ_1 and ρ_2 are both different from zero ($\rho_1 \& \rho_2 \neq 0$). Where $\rho_1 = \rho_2 = 0$ there is no endogeneity and an Ordinary Least Square (OLS) or logistic regression model is sufficient (Poirier and Ruud 1981).

It is worth stressing that y_{1i}, y_{2i}, I_i^*, equations (3)-(5), is a joint model and has a triviate density function. The data (1) and (2), however, are always bivariate in nature. The data do refer to three dependant variables in one model and each of the three variables is partially observed. I_i^* is observed as a dichotomous variable while the other two (y_{1i} & y_{2i}) are observed as continuous but conditional to the values of I_i^*.

y_{1i} is observed only if $I_i > 1$ and y_{2i} is observed only if $I_i < 0$ as presented in equations (1) and (2).

5.7. Endogeneity between anaemia during childhood and weight-for-age z-scores

Endogenous switching regression models are used as described above. Anaemia was jointly modelled with children's weight-for-age z-scores (continuous). Observed socioeconomic and demographic factors were accounted for and included in both equations for each country. Models that will be interpreted for each country include the following:

- One model with weight-for-age z-scores as the outcome for anaemic children
- Another model with weight-for-age z-scores as the outcome for children who are not anaemic (see Table 5.1).

The models that explore the risk factors associated with weight-for-age z-scores without accounting for endogeneity (using OLS) are presented to illustrate how the effects of other individual explanatory variables in the model are inconsistent and biased as a result of ignoring endogeneity between anaemia and weight-for-age z-scores. The results for both models where endogeneity is accounted for (simultaneous endogenous switching models) and the standards OLS regression models are presented in Tables 5.2, 5.4 and 5.6 respectively for each country. The coefficients of each individual variable estimated using endogenous switching regression models are presented on one side of the tables. On the other sides are the coefficients from standard OLS regression models.

For all three countries, the results suggest that anaemia is endogenous to weight-for-age z-scores; ρ_1 and ρ_2 are different to zero. Since ρ_1 and ρ_2 are different from zero, the correlation between the error terms of the two equations need to be accounted for. Otherwise the effect sizes of individual variables included in the model could be under/overestimated or in opposite direction. Both anaemia and weight-for-age z-scores might be influenced by not only the same observed factors, but also by the same unobserved factors not under study. The effects of individual variables estimated using standard Ordinary Least Square regression models are inconsistent and biased as follows:

1. The effect of some individual variables is underestimated;
2. The effects of other variables are overestimated;
3. The effects of some variables are in the opposite direction.

Commonly observed socioeconomic variables are presented and their effects are further discussed for each country. It should be noted that only results from endogenous switching regression models are interpreted; the OLS results are presented for comparison reasons only. Certain relevant indicators, such as presence of fever and diarrhoea, were not included in the models due to small number of observations.

5.7.1. Anaemia and weight-for-age z-scores in DRC

Conditional means weight-for-age z-scores by the selected characteristics (age, sex, maternal level of education, etc.) of the sampled children are presented in Table 5.1 according to whether they are anaemic or not. In total, 24% of children were classified as underweight and 71% were anaemic. Both anaemic and not anaemic children aged between 2 and 5 years old have a mean weight-for-age z-scores which are lower compared to younger children (less than 2 years olds). The average weight-for-age z-scores for males is lower than it is for females. However, there are no significant differences in the mean weight-for-age z-scores for anaemic children whether they were breastfed, consumed green leafy vegetables or red meat (see Table 5.1).

Table 5.1. Mean weight-for-age z-scores for anaemic and not anaemic children by children's characteristics in (DRC)

		Anaemic			Not anaemic		
Variable	Categories	Mean	P-value*	Sample	Mean	P-value*	Sample
Age			**<0.001**			**0.015**	
	<2 years	-0.89		779	-0.86		197
	2-5 years	-1.38		990	-1.12		513
Sex			**0.023**			**0.036**	
	Female	-1.09		876	-0.95		390
	Male	-1.23		893	-1.16		320
Maternal education			**<0.001**			**0.005**	
	None	-1.31		398	-1.25		169
	Primary	-1.26		843	-1.10		294
	Secondary	-0.89		528	-0.85		247
Ever breastfed			0.877			0.261	
	No	-1.17		518	-0.97		229
	Yes	-1.16		1251	-1.09		481
Mother anaemic			**0.076**			0.890	
	No	-1.10		805	-1.04		427
	Yes	-1.21		964	-1.06		283
Vegetables			0.133			**0.079**	
	No	-1.23		581	-1.16		251
	Yes	-1.13		1188	-0.99		459
Red meat			0.152			**0.008**	
	No	-1.22		672	-1.20		289
	Yes	-1.13		1097	-0.94		421
Wealth			**<0.001**			**0.036**	
	Poorest	-1.28		349	-1.29		113
	Below average	-1.35		354	-1.08		171
	Average	-1.13		385	-1.04		122
	Above average	-1.07		349	-0.80		160
	Wealthiest	-0.97		332	-1.10		144

N=2479; * p-value was obtained using two-samples comparison means t-test

The data also indicate that for almost all the selected characteristics of children (age, gender, maternal education, breastfeeding, whether the mother is anaemic, the consumption of vegetables and red meat) anaemic children have lower mean weight-for-age z-scores. On average, anaemic children aged between 2 and 5 years of age have mean a weight-for-age z-score which is 0.26 standard deviations lower than their counterparts whom are of the same age but are not anaemic. With regards to maternal level of education, children of mothers whom are educated at least with a primary level of education but who are anaemic have a mean weight-for-age z-score which is 0.16 standard deviations lower than those children whom mothers with the same level of education but are not anaemic (Table 5.1).

Results from simultaneous endogenous switching regression models

The results indicate that there is a strong correlation between unobserved factors of weight-for-age z-scores and anaemia (i.e. ρ_1 or ρ_2 is different from zero). Thus, anaemia is endogenous to weight-for-age z-scores. This suggests that some observed and unobserved factors that expose children to anaemia are also related with children's weight-for-age. The age, sex, maternal level of education, whether the mother is anaemic and household wealth status are factors associated with weight-for-age z-scores for anaemic children in DRC (Table 5.2). However, whether or not children were breastfed, consumed green leafy vegetables or meat are not found to be related with weight-for-age z-scores among anaemic children. Factors that are associated with weight-for-age z-scores for children who are not anaemic are sex, maternal level of education, the consumption of red meat and household wealth status.

Table 5.2. Estimated differences in means weight-for-age z-scores for anaemic and not anaemic children in DRC using endogenous switching and OLS models.

Variable	Category	Weight-for-age z-scores (ESM) Anaemia Yes		Weight-for-age z-scores (ESM) Anaemia No		Weight-for-age z-scores OLS Anaemia Yes		Weight-for-age z-scores OLS Anaemia No	
		Coef	SE	Coef	SE	Coef	SE	Coef	SE
Constant		-0.497	0.157	-0.650	0.545	-0.919	0.138	-1.238	0.231
Age	<2 years(Ref)								
	2-5 years	**-0.300***	0.073	-0.025	0.186	**-0.292***	0.064	**-0.162****	0.112
Sex	Female(Ref)								
	Male	**-0.235***	0.065	**-0.251****	0.108	**-0.167***	0.061	**-0.185****	0.098
Maternal education	None (Ref)								
	Primary	-0.014	0.085	0.095	0.133	0.034	0.079	0.164	0.124
	Secondary	**0.384***	0.093	**0.353***	0.137	**0.356***	0.086	**0.324****	0.131
Ever breastfed	No(Ref)								
	Yes	-0.087	0.077	-0.094	0.117	-0.093	0.072	-0.090	0.114
Mother anaemic	No(Ref)								
	Yes	**-0.282***	0.069	-0.225	0.149	**-0.111*****	0.062	-0.039	0.099
Vegetables	No(Ref)								
	Yes	0.051	0.078	0.052	0.116	0.007	0.071	**0.212****	0.107
Red meat	No (Ref)								
	Yes	-0.006	0.076	**0.190*****	0.112	0.048	0.073	0.054	0.112
Wealth	Poorest (Ref)								
	Below average	0.012	0.106	**0.293*****	0.172	-0.096	0.098	0.188	0.155
	Average	0.104	0.104	0.152	0.174	0.104	0.096	0.175	0.170
	Above average	**0.262****	0.106	**0.519***	0.170	**0.166*****	0.098	**0.432***	0.159
	Wealthiest	**0.326***	0.108	0.188	0.172	**0.254****	0.100	0.123	0.162
ρ_1		**-0.681**	**0.059**						
ρ_2		-0.448	0.267						

ESM: Endogenous switching model; Coef: Coefficients (estimates); SE (Standard error); Ref: reference category; ***: p< 1% **: p< 5% *: p< 10%

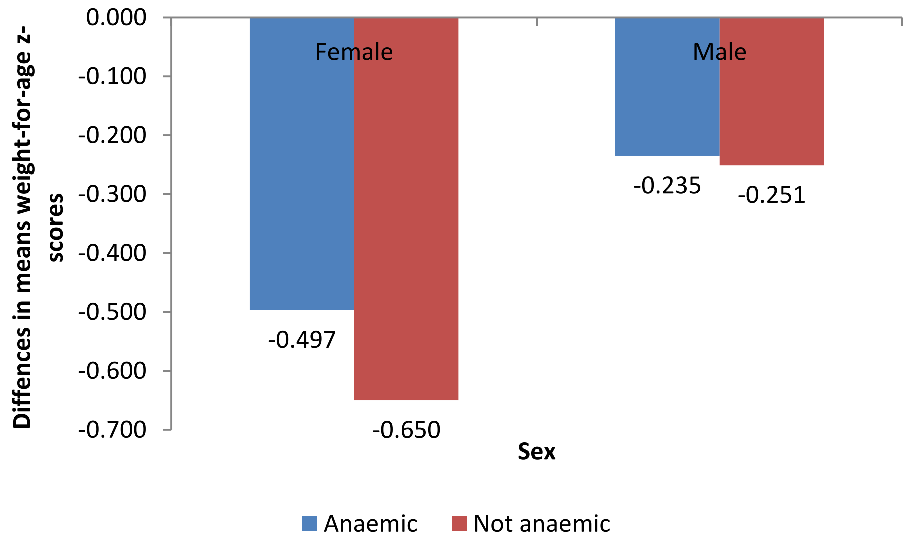
ρ_1 is the correlation coefficient of observed and unobserved factors between equations for weight-for-age z-scores and anaemia is equal to yes.

ρ_2 is the correlation coefficient of observed and unobserved factors between equations for weight-for-age z-scores and anaemia is equal to no.

For both anaemic and not anaemic children, sex, maternal level of education and household wealth status are common important factors that are influencing children's nutritional status. It is found that the estimated differences in means weight-for-age z-scores increases with an increased household wealth status for anaemic children. However, it is not the case for children who are not anaemic. For those not anaemic children there is no significant difference in the mean weight-for-age z-scores between children from households with average wealth status and those children from wealthiest households. Whether children consumed red meat was found to be related with their nutritional status only among children who were not anaemic. On average, not anaemic children who consumed red meat have a mean weight-for-age z-scores which is 0.190 higher than those who did not (Table 5.2). Children of anaemic mothers are not only more likely to be anaemic (Chapter 4) but also have a low mean weight-for-age z-score.

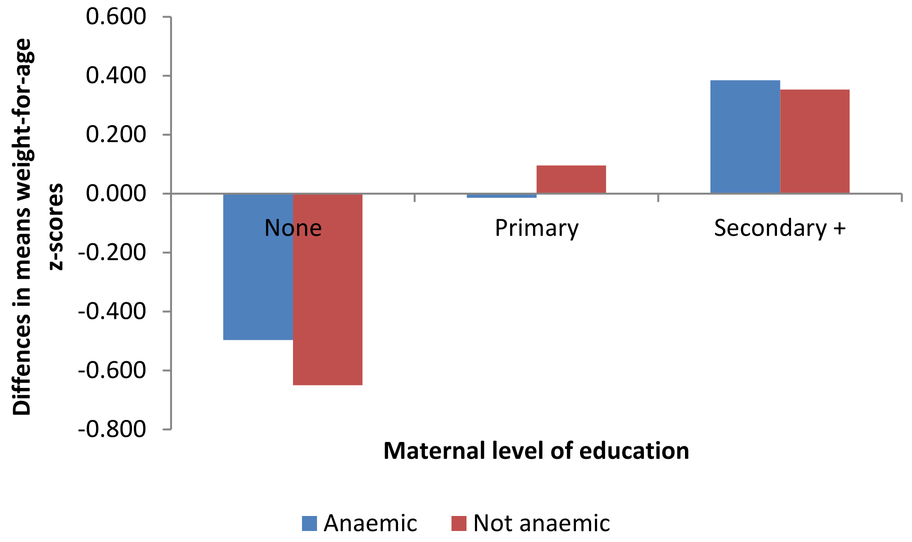
For both male and female children, not anaemic children have an average weight-for-age z-score which is worse than that of children who are anaemic as depicted in Figure 5.1 and Table 5.2. With regard to sex, the mean weight-for-age z-scores are lower for females regardless of whether they are anaemic or not compared with males.

Figure 5.1. Estimated differences in means weight-for-age z-scores for anaemic and not anaemic children in DRC by sex



The maternal level of education is another important factor related to children's nutritional status. For both anaemic and not anaemic children the results suggest that the estimated mean weight-for-age z-scores increases with an increased maternal level of education see; Figure 5.2 and Table 5.2. These results support previous findings which suggest that maternal level of education can have a positive impact on children's wellbeing (Gacek and Chrzanowska 2009).

Figure 5.2. Estimated differences in means weight-for-age z-scores for anaemic and not anaemic children in DRC by maternal level of education



Household wealth status is among many other factors that have an influence on the children's nutritional status in DRC. The consumption of red meat has a positive impact on the children's nutritional status for children who are not anaemic. This supports the findings from a previous study which reported that red meat consumption has a potential impact on iron intake and nutritional status (Kemper, Trotter et al. 2010).

5.7.2. Endogenous switching regression models vs OLS regression models

Results from both endogenous switching and standard OLS regression models as presented in Tables 5.2 suggest similar risk factors associated with children's weight-for-age z-scores in DRC. However, there are differences in the effect sizes of the estimates. With regards to children's sex (female category) for example, for both anaemic and non-anaemic children endogenous switching regression model indicates that children's mean weight-for-age z-scores are worse compared with the estimates produced using the standard OLS model. The estimates for primary education and whether children ate red meat are in the opposite directions, the endogenous switching regression model suggests a significant positive effect associated with the consumption of red meat for children who are not anaemic, which is underestimated when using standard OLS regression model. The correlation coefficients ρ_1 and ρ_2 are both different from zero and are negative but are significant only for ρ_1. Hence, ignoring this correlation will lead to a miss specified model with the possibility of inconsistent parameter estimates.

5.7.3. Anaemia and weight-for-age z-scores in Uganda

Summary statistics for weight-for-age z-scores for all the selected children characteristics are presented in Table 5.3. The data indicate that the children's mean weight-for-age z-scores for selected characteristics ranges from -0.92 to -1.43 for anaemic children and from -0.51 to -1.30 for non-anaemic children. For each of the selected characteristics anaemic children have relatively low mean weight-for-age z-scores compared to those children who are non-anaemic (Table 5.3). However, the observed differences in mean weight-for-age z-scores are not significant by sex, whether the mother is anaemic and whether the child was given red meat.

Table 5.3. Mean weight-for-age z-scores for anaemic and not anaemic children in Uganda

Variable	Total sample	Anaemia Yes			Anaemia No		
	1,786	Mean	p-value*	Sample	Mean	p-value*	Sample
Age			**<0.001**			**0.008**	
	<2 years	-1.37		669	-1.26		94
	2-5 years	-1.13		682	-0.90		341
Sex			0.655			0.607	
	Female	-1.24		669	-0.95		241
	Male	-1.26		682	-1.01		194
Maternal education			**<0.001**			**0.004**	
	None	-1.43		323	-1.14		89
	Primary	-1.23		875	-1.02		286
	Secondary	-0.96		153	-0.51		60
Ever breastfed			**0.024**			**0.011**	
	No	-1.12		316	-0.77		145
	Yes	-1.29		1035	-1.08		290
Mother anaemic			0.585			0.929	
	No	-1.23		596	-0.98		256
	Yes	-1.27		755	-0.97		179
Vegetables			**<0.001**			0.292	
	No	-1.16		903	-0.93		284
	Yes	-1.43		448	-1.06		151
Red meat			0.226			0.729	
	No	-1.26		1210	-0.98		397
	Yes	-1.13		141	-0.91		38
Wealth			**<0.001**			**0.007**	
	Poorest	-1.42		339	-1.30		80
	Below average	-1.21		304	-1.01		92
	Average	-1.29		282	-1.04		100
	Above average	-1.26		244	-0.91		74
	Wealthiest	-0.92		182	-0.63		89

N=1,786; * p-value was obtained using two-samples comparison means t-test.

The estimated differences in means weight-for-age z-scores using simultaneous regression models and ordinary least square are presented in Table 5.4. In Uganda, risk factors associated with weight-for-age z-scores among anaemic children are age, sex, maternal level of education, maternal anaemia status and whether children consumed green leafy vegetables.

Table 5.4. Estimated differences in means weight-for-age z-scores for anaemic and non-anaemic children in Uganda using endogenous switching and OLS models

Variable	Category	**Weight-for-age z-scores (ESM)**		**Weight-for-age z-scores (ESM)**		**Weight-for-age z-scores OLS**			
		Anaemia Yes		Anaemia No		Anaemia Yes		Anaemia No	
		Coef	SE	Coef	SE	Coef	SE	Coef	SE
Constant		-1.800	0.140	-0.720	0.306	-1.213	0.121	-1.208	0.231
Age	<2 years(Ref)								
	2-5 years	**-0.692*****	0.089	**-0.693*****	0.066	0.196	0.134	-0.137	0.269
Sex	Female(Ref)								
	Male	**0.016*****	0.010	-0.017	0.115	-0.049	0.064	-0.041	0.114
Maternal education	None (Ref)								
	Primary	**0.149****	0.086	-0.003	0.146	**0.151****	0.079	0.008	0.147
	Secondary	**0.329****	0.137	0.351	0.220	**0.331***	0.127	0.375	0.221
Ever breastfed	No(Ref)								
	Yes	-0.017	0.084	**-0.238*****	0.125	**-0.189****	0.077	**-0.276*****	0.124
Mother anaemic	No(Ref)								
	Yes	**0.150****	0.072	0.079	0.123	-0.016	0.065	0.022	0.117
Vegetables	No(Ref)								
	Yes	**-0.300***	0.075	-0.115	0.118	**-0.275***	0.069	-0.107	0.206
Red meat	No (Ref)								
	Yes	0.151	0.103	-0.092	0.205	0.087	0.105	-0.114	0.119
Wealth	Poorest (Ref)								
	Below average	0.106	0.103	0.237	0.181	0.154	0.094	0.261	0.182
	Average	-0.055	0.106	0.196	0.182	0.034	0.098	0.250	0.180
	Above average	-0.002	0.112	0.279	0.195	0.024	0.103	0.301	0.196
	Wealthiest	0.181	0.128	**0.393*****	0.208	**0.317***	0.119	**0.473***	0.202
ρ_1		**0.764**	**0.045**						
ρ_2		0.248	0.163						

ESM: Endogenous switching model; Coef: Coefficients (estimates); SE (Standard error); Ref: reference category; ***: p< 1% **: p< 5% *: p< 10%

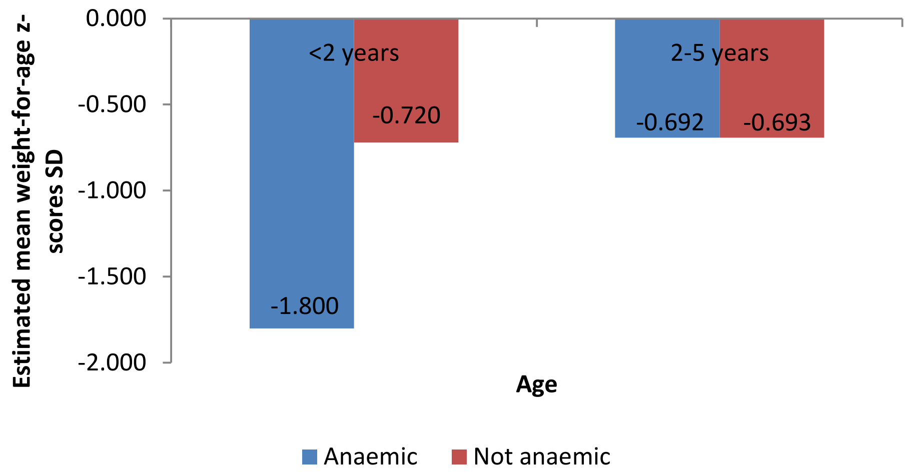
ρ_1 is the correlation coefficient of observed and unobserved factors between equations for weight-for-age z-scores and anaemia is equal to yes.

ρ_2 is the correlation coefficient of observed and unobserved factors between equations for weight-for-age z-scores and anaemia is equal to no

Anaemic male children have an estimated mean weight-for-age z-score which is 0.016 higher than females. Breastfeeding and household wealth status are related to children's weight-for-age z-scores for non anaemic children only. The results suggest that children who are not anaemic and were not breastfed have an average weight-for-age z-score which is -0.720 standard deviation lower than it is for those children who were breastfed (Table 5.4).

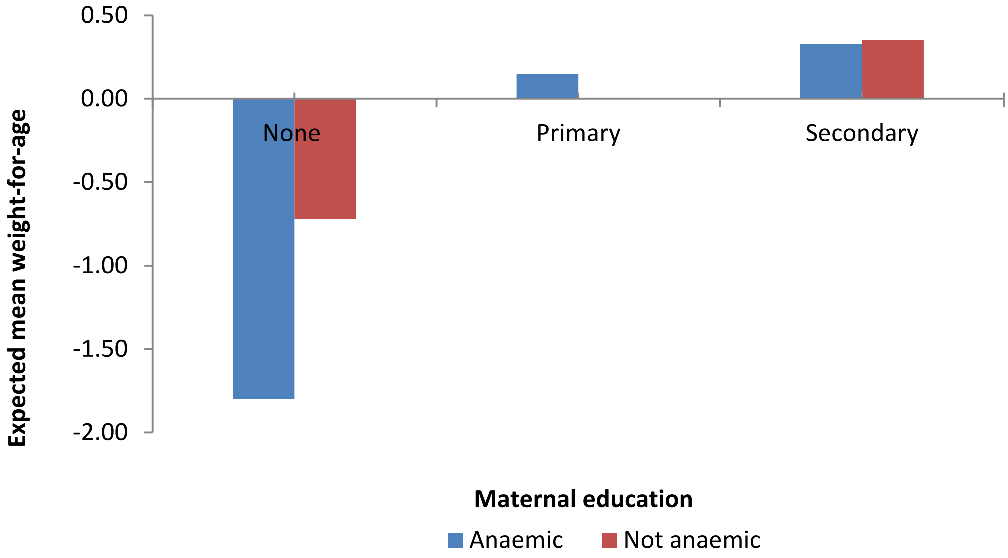
Mean weight-for-age was also predicted from the model for each age group. For both anaemic and non-anaemic children, those aged less than 2 years of age have expected mean weight-for-age z-scores, which are lower compared to those children aged between 2 and 5 years (Figure 5.3). It is recommended that infant should be exclusively breastfed during their first six months of life, and complementary food should be introduced after the first six months while breastfeeding continue (WHO 2001). Efforts to introduce complementary foods in developing countries often meet with not only economical, but also behavioural and cultural challenges. Child feeding in less developed countries tends to be steeped in traditional practices and beliefs (Khor, Noor Safiza et al. 2009).

Figure 5.3. Estimated differences in means weight-for-age z-scores by age in Uganda



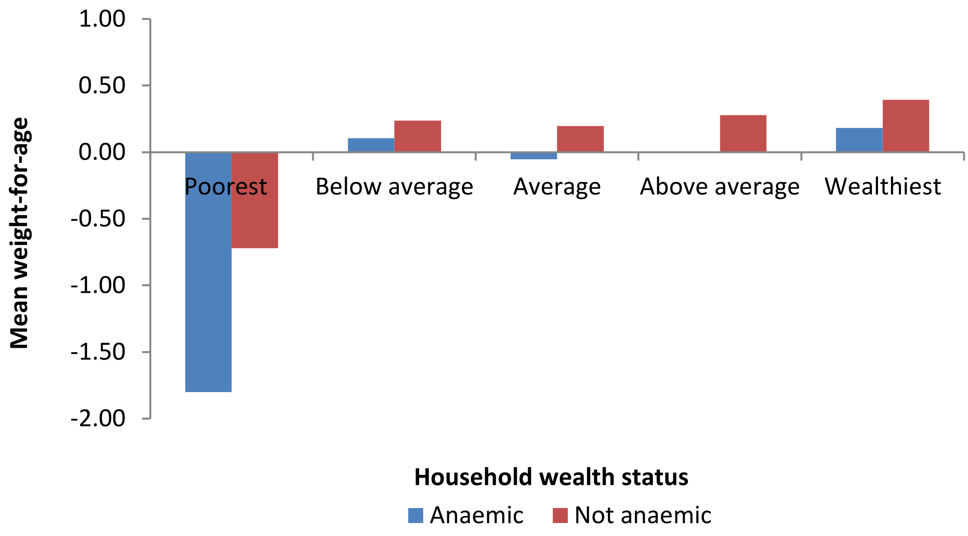
Maternal level of education is another factor significantly related to children's nutritional status in Uganda. As it was found in DRC, in Uganda children's mean weight-for-age z-scores increases with an increased maternal level of education (Figure 5.4 and Table 5.4).

Figure 5.4. Estimated differences in mean weight-for-age z-scores for anaemic and not anaemic children by maternal level of education in Uganda



Household wealth status is another important factor associated with children's nutritional status for those children who are not anaemic in Uganda. There is a clear increase between poorest and the below average for those children who are anaemic. The pattern is not that different from those who are not anaemic (Figure 5.5).

Figure 5.5. Estimated mean weight-for-age z-scores by households wealth status for anaemic and not anaemic children in Uganda



5.7.4. Endogenous switching regression models vs OLS regression models in Uganda

Results from both endogenous switching regression models and standard OLS regression models for Uganda as presented in Table 5.4 are different in two aspects. One in terms of risk factors associated with children's weight-for-age z-scores, and two in term of the effect sizes of the estimates. Endogenous regression model suggests that for both anaemic or non-anaemic children, the mean weight-for-age z-scores differ significantly by age, sex, maternal level of education, whether the mother is anaemic, household wealth status and with the consumption of green leafy vegetable. However, using standard OLS regression model, only maternal level of education, breastfeeding, the consumption of green leafy vegetables and household wealth status are factors significantly associated with children's weight for age. Children's age and sex and whether the mother is anaemic are not associated with children's weight-for-age z-scores. In addition, the effect sizes of some individual factors included in the model are not only under or overestimated using OLS but also they are in the opposite directions. This is the reason why endogenous regression models are used to account for endogeneity between anaemia and weight-for-age z-scores. The correlation coefficients ρ_1 and ρ_2 are both different from zero and are positive but are significant only for ρ_1. Again, these results suggest that ignoring the correlation between weight-for-age z-scores and anaemia will lead to a miss specified model with the possibility of inconsistent parameter estimates.

5.7.5. Anaemia and weight-for-age z-scores in children in Malawi

The same potential risk factors selected for DRC and Uganda were also examined for Malawi. Table 5.5 presents the basic summary, mean weight-for-age z-scores for anaemic and not anaemic children for the selected characteristics. It indicates that in Malawi, anaemia during childhood has an impact on children's nutritional status. Mean weight-for-age z-scores for anaemic children are lower for children aged between 2 and 5 years old, males, children of mothers with primary education or lower, those children whose mothers are anaemic, those children who were given red meat, are from households with wealth below the average and above the average. However, these differences are not statistically significant. The data suggest that the only significant difference is observed among anaemic children whose mothers are anaemic. Anaemic children whose mothers are also anaemic have significant lower mean weight-for-age z-scores compared with their counterparts whose mothers are not anaemic.

Table 5.5. Mean weight-for-age z-scores for anaemic and not anaemic children in Malawi

Variable	Category	Anaemia Yes			Anaemia No		
		Mean	p-value*	Sample	Mean	p-value*	Sample
Age			0.148			0.964	
	<2 years	-0.86		789	-0.89		180
	2-5 years	-1.01		191	-0.90		73
Sex			0.103			0.927	
	Female	-0.83		497	-0.90		134
	Male	-0.96		483	-0.89		119
Maternal education			0.753			0.256	
	None	-0.88		242	-0.67		56
	Primary	-0.91		638	-0.99		155
	Secondary	-0.82		100	-0.81		42
Ever breastfed			0.316			0.965	
	No	-0.97		201	-0.89		73
	Yes	-0.87		779	-0.89		180
Mother anaemic			**0.022**			0.936	
	No	**-0.81**		533	-0.89		167
	Yes	**-0.99**		447	-0.91		86
Vegetables			0.645			0.953	
	No	-0.91		419	-0.90		117
	Yes	-0.88		561	-0.89		136
Red meat			0.170			0.661	
	No	-0.85		634	-0.87		169
	Yes	-0.97		346	-0.93		84
Wealth			0.333			0.974	
	Poorest	-0.86			-0.96		22
	Below average	-0.92			-0.82		47
	Average	-0.76			-0.96		60
	Above average	-0.93			-0.89		81
	Wealthiest	-1.03			-0.85		43

N=1,233; * p-value was obtained using two-samples comparison means t-test.

Table 5.6 presents the results of the endogenous switching regression model between anaemia and weight-for-age z-scores in Malawi. Besides other unknown factors that might affect the children's nutritional status, it is suggested that in Malawi, the age and household wealth status are the only factors associated with weight-for-age z-scores for anaemic children.

Table 5.6. Estimated differences in means weight-for-age z-scores for anaemic and not anaemic children in Malawi using endogenous switching and OLS models

Variable	Category	Weight-for-age z-scores (ESM)		Weight-for-age z-scores (ESM)		Weight-for-age z-scores OLS			
		Anaemia Yes		Anaemia No		Anaemia Yes		Anaemia No	
		Coef	SE	Coef	SE	Coef	SE	Coef	SE
Constant		-0.875	0.224	0.971	0.213	-0.208	0.231	-0.499	0.447
Age	<2 years(Ref)								
	2-5 years	**-0.399*****	0.223	0.147	0.305	-0.161	0.205	-0.137	0.269
Sex	Female(Ref)								
	Male	-0.039	0.132	-0.094	0.181	-0.054	0.120	-0.018	0.161
Maternal education	None (Ref)								
	Primary	-0.182	0.157	-0.316	0.229	-0.196	0.143	**-0.388 *****	0.209
	Secondary	-0.305	0.248	0.207	0.323	-0.051	0.231	-0.193	0.279
Ever breastfed	No(Ref)								
	Yes	0.131	0.221	-0.192	0.302	0.002	0.202	-0.146	0.268
Mother anaemic	No(Ref)								
	Yes	0.136	0.133	**-0.375*****	0.195	-0.094	0.121	-0.050	0.170
Vegetables	No(Ref)								
	Yes	-0.041	0.146	-0.155	0.215	-0.141	0.132	-0.087	0.193
Red meat	No (Ref)								
	Yes	0.109	0.140	-0.138	0.206	-0.023	0.127	0.020	0.186
Wealth	Poorest (Ref)								
	Below average	-0.361	0.219	0.520	0.363	-0.090	0.197	0.167	0.333
	Average	-0.006	0.214	0.358	0.356	0.313	0.192	-0.069	0.325
	Above average	**-0.372*****	0.206	0.560	0.348	-0.060	0.185	0.071	0.312
	Wealthiest	**-0.432*****	0.246	0.533	0.387	-0.120	0.222	0.118	0.351
ρ_1		**0.934**	**0.011**						
ρ_2		**-0.870**	**0.050**						

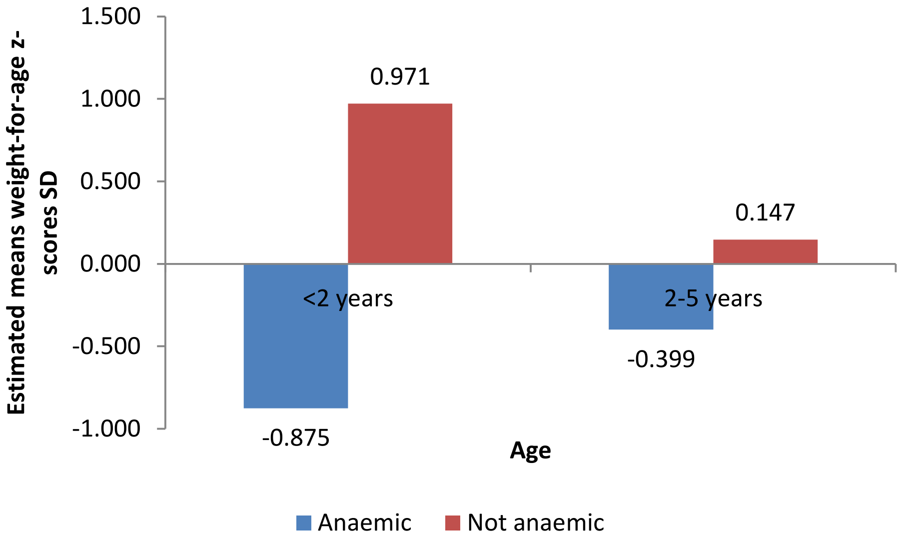
ESM: Endogenous switching model; Coef: Coefficients (estimates); SE (Standard error); Ref: reference category; ***: p< 1% **: p< 5% *: p< 10%

ρ_1 is the correlation coefficient of observed and unobserved factors between equations for weight-for-age z-scores z-scores and anaemia is equal to yes.

ρ_2 is the correlation coefficient of observed and unobserved factors between equations for weight-for-age z-scores and anaemia is equal to no

As it was found in Uganda, anaemic children aged younger children (aged less than 2 years of age (Figure 5.6) and those from poorest households are associated with lower mean weight-for-age z-scores and the difference is significant (Table 5.6) in Malawi.

Figure 5.6. Estimated differences in means weight-for-age z-scores by age groups in Malawi



For not anaemic children, it is estimated that where the mother is anaemic is the only factor related with weight-for-age z-scores (Table 5.6). Surprisingly, where the children were breastfed or the consumption of green leafy vegetables or red meat were not found to be related to children's nutritional status in Malawi.

5.7.6. Endogenous switching regression models vs OLS regression models

Results from both endogenous switching regression and standard regression models presented in Table 5.6 suggest that differences in the estimates produced using these two models are as argued for DRC and Uganda. The results suggest that anaemia is endogenous to weight-for-age z-scores (non zero correlation between the error terms) and that if it is ignored, the relationship observed using OLS might be different from the true relationships. Endogenous model suggests that the age, whether the mother is anaemic and household wealth status are among many other factors related with children's weight-for-age z-scores. But the OLS suggest something different that it is only maternal level of education which is significantly associated with children's weight-for-age z-scores in Malawi. Again the effect size of some factors is under or overestimated, while for other factors (such as whether the mother is anaemic and the consumption of red meat) the effect is in the opposite directions. The results are similar to those observed in DRC and Uganda. The correlation coefficients ρ_1 and ρ_2 are both different from zero. The correlation coefficients are positive for ρ_1 and negative for ρ_2, but are significant only for ρ_1. Again, this means that ignoring the correlation between weight-for-age z-scores and anaemia will lead to a miss specified model with the perhaps inconsistent parameter estimates.

5.8. Similarities and differences in the children's nutritional status (weight-for-age z-scores) between countries

This section discusses the similarities and differences in the children's nutritional status. Tables 5.7 and 5.8 present the estimated differences in means weight-for-age z-scores for anaemic and not anaemic children by country. The results suggest that anaemic children have significant lower mean weight-for-age z-scores compared to their counterparts who are not anaemic (Tables 5.7 and 5.8). For anaemic children, the age, sex, maternal level of education, whether the mother is anaemic, whether children ate vegetables and household wealth status are important factors associated with the children's weight-for-age z-scores in at least one country.

Age is the commonest risk factor associated with weight-for-age z-scores for anaemic children in all the three countries. The consumption of green leafy vegetables for children who are anaemic is found to be associated with children's weight-for-age z-scores only in Uganda but not in DRC and Malawi. Anaemic children who consumed green leafy vegetables have an average weight-for-age z-score which is 0.30 standard deviations lower than that of anaemic children who did not consume green leafy vegetables.

Maternal level of education, sex, whether the mother is anaemic are found to be significantly related with weight-for-age z-scores for anaemic children in DRC and Uganda but not in Malawi (Table 5.7). Surprisingly, in all three countries, anaemic children whose mothers are not anaemic are associated with lower mean weight-for-age z-cores compared with those anaemic children whose mothers are anaemic. This could reflect the fact that children of mothers with poor nutrition are likely to be cared for and get micro supplements such as Vitamin A. There is diversity in the significant covariates between the three countries in the models which suggest a need for programs to adopt country-specific approach to tackling undernutrition.

Table 5.7. Estimated differences in means weight-for-age z-scores for anaemic children by country

Variable	**Category**	**DRC**		**Uganda**		**Malawi**	
		Coef	SE	Coef	SE	Coef	SE
Constant		-0.497	0.157	-1.800	0.140	-0.875	0.224
Age	<2 years(Ref)						
	2-5 years	**-0.300***	0.073	**-0.692*****	0.089	**-0.399*****	0.223
Sex	Female(Ref)						
	Male	**-0.235***	0.065	**0.016*****	0.010	-0.039	0.132
Maternal education	None (Ref)						
	Primary	-0.014	0.085	**0.149****	0.086	-0.182	0.157
	Secondary	**0.384***	0.093	**0.329****	0.137	-0.305	0.248
Ever breastfed	No(Ref)						
	Yes	-0.087	0.077	-0.017	0.084	0.131	0.221
Mother anaemic	No(Ref)						
	Yes	**-0.282***	0.069	**0.150****	0.072	0.136	0.133
Vegetables	No(Ref)						
	Yes	0.051	0.078	**-0.300***	0.075	-0.041	0.146
Red meat	No (Ref)						
	Yes	-0.006	0.076	0.151	0.103	0.109	0.140
Wealth	Poorest (Ref)						
	Below average	0.012	0.106	0.106	0.103	-0.361	0.219
	Average	0.104	0.104	-0.055	0.106	-0.006	0.214
	Above average	**0.262****	0.106	-0.002	0.112	**-0.372*****	0.206
	Wealthiest	**0.326***	0.108	0.181	0.128	**-0.432*****	0.246
$\boldsymbol{\rho_1}$		**-0.681**	**0.059**	**0.764**	**0.045**	**0.934**	**0.011**
$\boldsymbol{\rho_2}$		-0.448	0.267	0.248	0.163	**-0.870**	**0.050**

Household wealth status is an important factor associated with the children's weight-for-age z-scores in DRC and Malawi but not in Uganda. For anaemic children, the mean weight-for-age z-score increases with an increased household wealth status in DRC as depicted in Figure 5.7. By household wealth, children in the lowest wealth quintiles are associated with lower mean weight-for-age in all three counties. These results are as one would expect them to be. Poverty is predictive of poor nutrition among children (Bhattacharya, Currie et al. 2004).

Figure 5.7. Estimated differences in means weight-for-age z-scores by household wealth status in DRC, Uganda and Malawi for anaemic children.

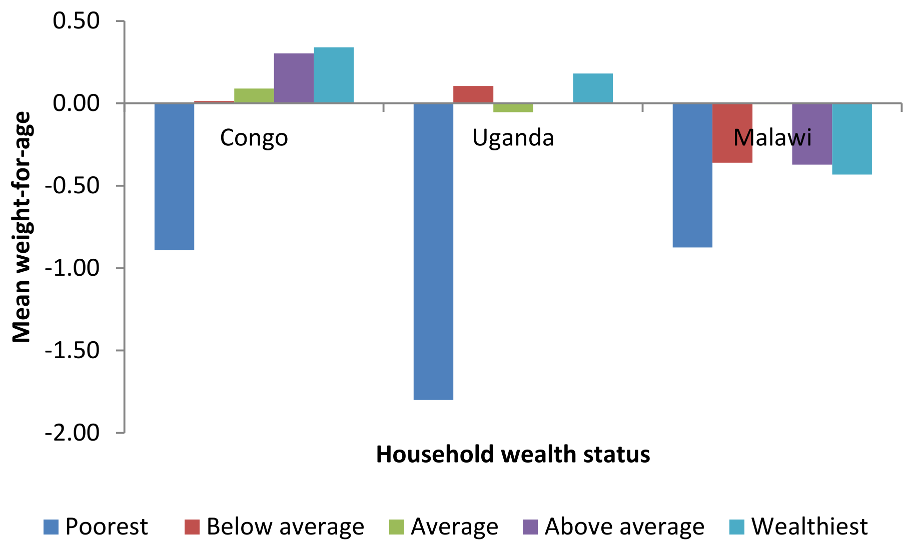
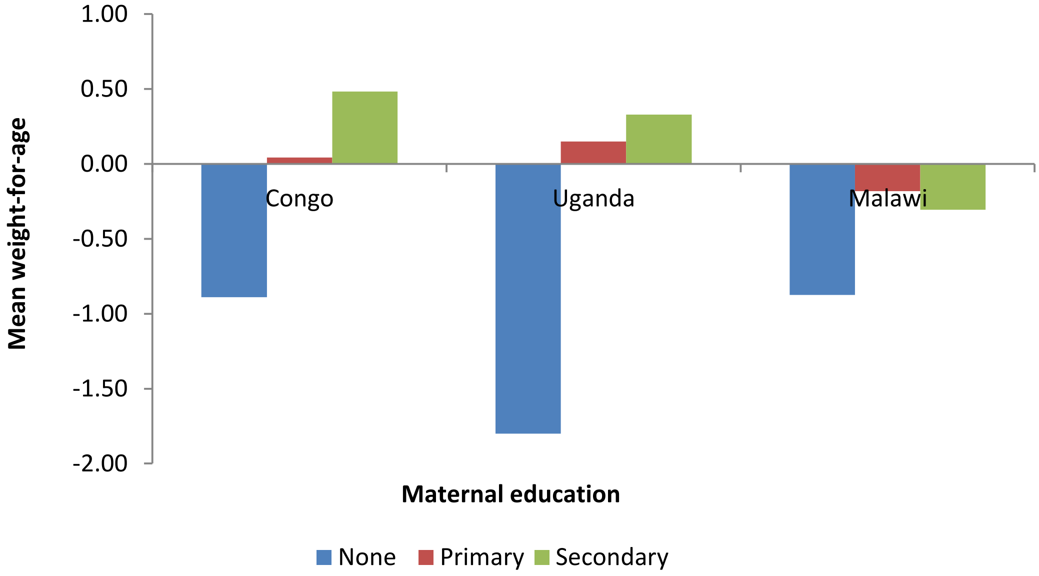


Table 5.8 Estmated differences in means weight-for-age z-scores for not anaemic children by country

Variable	**Category**	**DRC**		**Uganda**		**Malawi**	
		Coef	SE	Coef	SE	Coef	SE
Constant		-0.650	0.545	-0.720	0.306	0.971	0.213
Age	<2 years(Ref)						
	2-5 years	-0.025	0.186	**-0.693*** **	0.066	0.147	0.305
Sex	Female(Ref)						
	Male	**-0.251** **	0.108	-0.017	0.115	-0.094	0.181
Maternal education	None (Ref)						
	Primary	0.095	0.133	-0.003	0.146	-0.316	0.229
	Secondary	**0.353***	0.137	0.351	0.220	0.207	0.323
Ever breastfed	No(Ref)						
	Yes	-0.094	0.117	**-0.238*** **	0.125	-0.192	0.302
Mother anaemic	No(Ref)						
	Yes	-0.225	0.149	0.079	0.123	**-0.375*** **	0.195
Vegetables	No(Ref)						
	Yes	0.052	0.116	-0.115	0.118	-0.155	0.215
Red meat	No (Ref)						
	Yes	**0.190*** **	0.112	-0.092	0.205	-0.138	0.206
Wealth	Poorest (Ref)						
	Below average	**0.293*** **	0.172	0.237	0.181	0.520	0.363
	Average	0.152	0.174	0.196	0.182	0.358	0.356
	Above average	**0.519***	0.17	0.279	0.195	0.560	0.348
	Wealthiest	0.188	0.172	**0.393*** **	0.208	0.533	0.387
ρ_1		**-0.681**	**0.059**	**0.764**	**0.045**	**0.934**	**0.011**
ρ_2		-0.448	0.267	0.248	0.163	**-0.870**	**0.050**

The maternal level of education is related to the children's weight-for-age z-scores only in DRC and Uganda but not in Malawi as presented in Figure 5.8. The estimated mean weight-for-age z-scores increase with an increased maternal level of education in both DRC and Uganda. These results support previous findings which suggest that maternal level of education can have a positive impact on the children's well-being (Gacek and Chrzanowska 2009).

Figure 5.8. Mean weight-for-age z-scores by maternal level of education in DRC, Uganda and Malawi.



Model Diagnostics

It is argued that the endogenous switching regression model approach relies on the joint normality of the error terms in the binary and continuous equations (Vytlacil and Yildiz 2007; Kim, Piger et al. 2008).
The joint normality assumption between the error term of equation (3) and the error terms of equations (4) and (5) as shown in section 5.5 is an important aspect in the estimation of the endogenous switching regression model. The normality assumption was tested. The results for all three countries suggest that the residuals are approximately normally distributed (see Appendix 5.3, 5.4 and 5.5).

5.9. Potential unobserved factors of anaemia during childhood and the children's nutritional status.

Besides well-known factors that might directly or indirectly influence children's nutritional status there are many other unobserved potential factors that could affect the children's nutritional status. Since some of the factors by their nature cannot be observed or quantified they escape the investigator’s attention. Cultural norms and individual behavioural factors such as dietary intake by nature can be difficult to quantify. Behavioural factors are affected not only by personal characteristics (e.g. genetic profile, age and sex) but by interaction with larger social, environmental, economic and cultural norms (Kipke, Iverson et al. 2007). In some cultural food taboos, people seem to believe that certain food items should not be eaten by children or women of childbearing age (Levine and Kowlessar 1962). Food taboos not only deprive children or women of protein, iron sources and other vitamins but also reduce calories intake (Levine and Kowlessar 1962; Bwibo and Neumann 2003). Hence, cultural restrictions need to be considered for as risk factors of poor nutritional status. For example, a study in Nigeria showed that many foods that women of reproductive age (especially pregnant) avoid for cultural reasons are foods items which provide most of the key nutrients (e.g. calcium, iron, Vitamin A, folic acid or Vitamin C) needed for adequate nutrition (Brabin, Hakimi et al. 2001). In India for example, women believe that taking iron supplements (tablets) or vitamin tablets during pregnancy will cause them to have big babies, resulting in difficult deliveries (Bledsoe and Goubaud 1985). Poor nutritional status may also be influenced by the behaviours of other household members who care for children (Bentley and Black 1994).

More general distal factors that are unobserved could in turn influence the individual cultural and socioeconomic factors. For instance, the general economic status of the country will influence the socioeconomic status of households, affect food availability and limit access to appropriate food. Environmental conditions will affect the amount of food available in general and therefore the nutrients available to mothers and their children. Political instability is another distal factor which might affect the economy, social and cultural fabrics of a society. The socioeconomic fallout includes pauperising of communities, habitat destruction, disease transmission, and clearing for crops and grazing of cattle. All these factors could partially reveal the high level of poor nutritional status in some Sub-Saharan African countries.

5.10. Discussion and Conclusion

The aim of this chapter was to investigate the links between anaemia and the children's nutritional status (weight-for-age z-scores). Simultaneous endogenous switching regression models were fitted to the data.

For all three countries, the results suggest that anaemia is endogenous to weight-for-age z-scores; there is a strong correlation between anaemia and weight-for-age z-scores; ρ_1 and ρ_2 are different to zero. The correlation coefficients ρ_1 and ρ_2 are both different from zero and are positive/negative and are significant at least for one equation for each country. These results suggest that ignoring this significant correlation between weight-for-age z-scores and anaemia will lead to a missspecified model with the possibility of inconsistent parameter estimates. Both anaemia and weight-for-age z-scores might be influenced by not only the same observed factors, but also by the same unobserved factors not under study. This chapter has contributed in identification of subgroups of the child population that are at increased risk of faltered growth. Significant differences, especially with regard to weight-for-age z-scores are suggested among different subgroups of children within DRC, Uganda and Malawi. Among the observed factors, the results suggest that the age, sex, whether the mother is anaemic, maternal level of education and household wealth status are factors associated with weight-for-age z-scores for anaemic and non-anaemic children at least in one of the three countries.

Anaemic children are associated with lower mean weight-for-age z-scores compared with their counterparts with the same socioeconomic and demographic characteristics but who are not anaemic. Children aged <2 years old, anaemic or not, are associated with low mean weight-for-age z-scores. Large demand for iron during growth and insufficient intake of iron in children's usual diet at this age are among known reasons for greater vulnerability of children under the age of two (Engstrom, Castro et al. 2008). This could be a result of non-appropriate amount and type of food when breast milk stops (Beard 1995; McCann and Ames 2007). It is argued that as infants mature, their food and feeding patterns must continually change. When infants progress from needing to be fed to feeding themselves, this step of feeding themselves might make it difficult to consume the amount of nutrients required than when they are fed by someone else due to early eating skills development (McCann and Ames 2007). Another factor which could explain lower mean weight-for-age z-scores among the youngest age group is infections due to the introduction of foods which might increase children exposure to infections and susceptibility to illness.

Maternal level of education is another important factor associated with children weight-for-age z-scores and anaemia in DRC and Uganda. Mean weight-for-age z-scores increase with an increased maternal level of education. A positive effect of maternal level of education on nutritional status and eating behaviour and health of their children has been documented elsewhere(Boyle, Racine et al. 2006; Gacek and Chrzanowska 2009). D and Chrzanowska 2009). Differences in the significant covariates between the three countries in the models suggest the need for programs to adopt country-specific approach to tackling under nutrition.

This chapter has highlighted the fact that anaemia and weight-for-age z-scores are strongly correlated. Studies pertaining to anaemia and weight-for-age z-scores should account for the strong correlation between both. Where the correlation (endogeneity) is ignored, both the magnitudes and the signs of the coefficients in the Ordinary Regression Models can be misleading. The effects of individual variables estimated using the standard Ordinary Least Square regression models are inconsistent and biased. The effect of some individual variables is underestimated; thus some are overestimated and the effects of other variables are in the opposite direction. The estimates from both OLS and endogenous models are different and erroneous results could be obtained if endogeneity was not accounted for.

The chapter also suggest that socioeconomic factors not only increase children's risk of anaemia but also expose children to lower weight-for-age. The study design limits the interpretation of cause and effect; however, regardless of causality, these findings suggest that both anaemia and weight-for-age z-scores are influenced by the same observed and unobserved factors. Some of socioeconomic and demographic factors that could expose children to the risk of having anaemia might also be related to the children's weight-for-age z-scores. Possible unobserved factors include the distal extrinsic factors such as economic decline, demographic transitions, political conflicts and cultural behavioural factors (food taboos) that are even more important in determining nutritional status and its relation to the children's health and well-being in these three countries.

Socioeconomic and demographic factors influence decisions on pattern of feeding and nutritional status. Dietary interventions to treat anaemia and prevent poor nutritional status are important and should address several micronutrients in addition to maternal education, food availability, and access and dietary messages.

CHAPTER 6
The burden of anaemia among women in DRC, Uganda and Malawi

6.1. Introduction

Anaemia among women as depicted in the conceptual framework (Figure 2.2.) has many causes which can be grouped into three broad categories which are nutritional, biological and other causes (Riley, Ko et al. 2007). Socioeconomic and demographic factors can also interact with these causes to influence the epidemiology of anaemia. The results from Chapters 4 and 5, which explore socioeconomic and demographic risk factors associated with anaemia in children and children's nutritional status, suggest that besides well-known factors associated with anaemia in children and children's nutritional status, maternal health status (whether the mother is anaemic) is an important risk factor for children's nutritional status and wellbeing. Not only do the results suggest that children of anaemic mothers are found to be associated with an increased risk of anaemia but also children of anaemic mothers have lower mean weight-for-age z-scores. The impacts of maternal health on child nutritional status and wellbeing have been discussed elsewhere (Bledsoe and Goubaud 1985; Victora, Adair et al. 2008). Understanding the socioeconomic, demographic and environmental factors associated with anaemia in women is vital and could not only help to obtain the full picture of the epidemiology of anaemia but also it could help to plan integrated measures at households or communities for both women and children.

This chapter investigates not only the prevalence of anaemia but also the social, demographic and environmental factors associated with anaemia among women. The chapter aims to answer the following research questions:

(1) *What is the prevalence of anaemia among women in the selected countries?*

(2) *What are the socioeconomic and demographic factors associated with anaemia among these women in each country?*

(3) *What are the common risk factors of anaemia for both women and children?*

Retrospective cross sectional Demographic and Health Surveys from DRC 2007, Uganda 2006 and Malawi 2004 are used. Multilevel logistic regression models are used to estimate and quantify where possible differences in women's risk of having anaemia which are not explained by the observed socioeconomic and demographic factors.

There are three sections to this chapter. After the introduction, section two investigates the burden of anaemia among women in DRC, Uganda and Malawi by the selected socioeconomic and demographic factors. Section three then investigates the impact of the selected potential social risk factors on women's probability of having anaemia. In this section, socioeconomic and demographic factors that are suggested to be associated with anaemia are further explored including interactions. This section further makes cross-country comparisons and explains the potential unobserved differences due to communities and households level factors where possible and discusses common risk factors of anaemia among both women and their children.

6.2. The prevalence of anaemia by socioeconomic characteristics

Univariate methods using Chi-square tests are applied. The results are presented in Figure 6.1 and in Tables 6.1 to 6.3. It is found that the prevalence of anaemia among women in these three countries is high and almost half of women of reproductive age are anaemic (see Figure 6.1). Anaemia is slightly lower in Malawi and highest in DRC. Further investigation will need to be carried out to see whether cross country differences suggested by the data are statistically significant.

Figure 6.1. The prevalence of anaemia among women by country

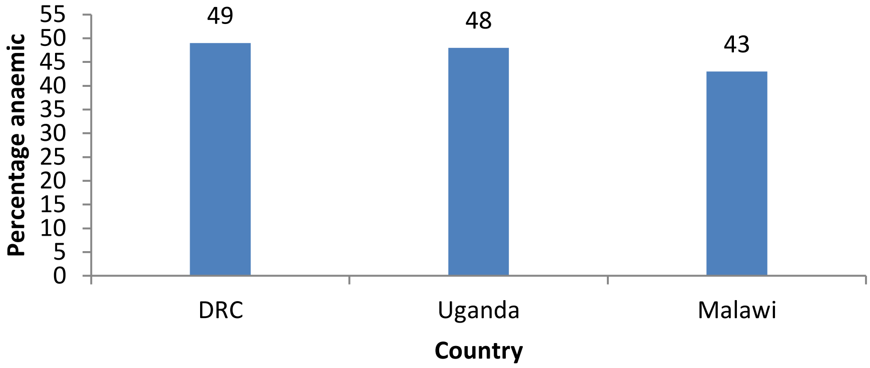


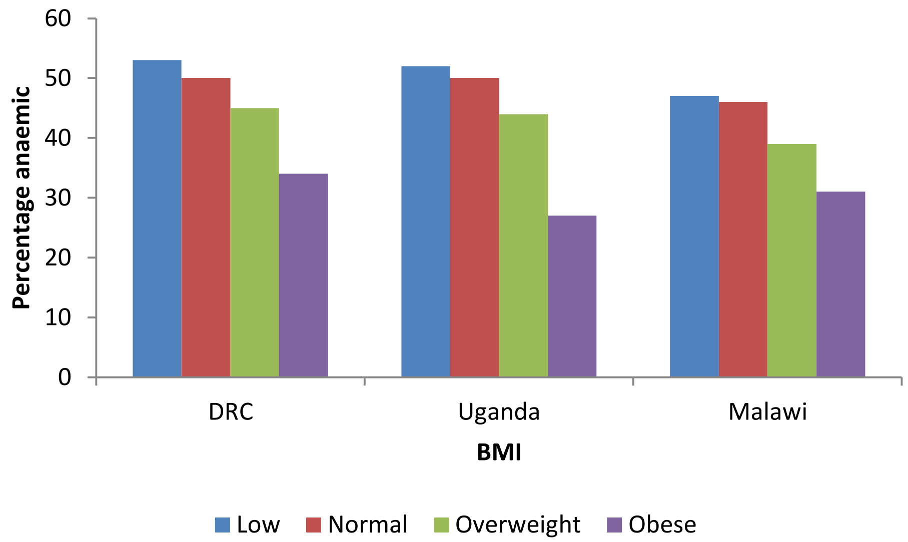
Table 6.1. Individual level factors associated with anaemia in women in all three countries

Variable	Category	DRC		Uganda		Malawi	
		%	Sample	%	Sample	%	Sample
Current age		**		**		**	
	15-24	48	1,950	46	1,167	43	1,203
	25-34	52	1,431	49	902	44	864
	35+	52	1,251	52	748	49	682
Age at 1st birth		NS		NS		NS	
	<15	54	232	53	165	40	184
	15-19	51	1,806	51	1,373	44	1,435
	20-24	50	1,054	51	514	47	537
	25+	53	282	55	92	53	78
Parity		**		**		NS	
	Zero	48	1,981	45	1,120	46	963
	One	53	1,238	51	730	46	955
	Two	50	1,121	52	772	42	740
	Three+	49	291	54	195	41	91
BMI		***		***		**	
	Low	53	1,565	52	851	47	649
	Normal	50	2,421	50	1,525	46	1,695
	Overweight	45	469	44	342	39	307
	Obese	34	119	27	91	31	72
Pregnant		**		***		NS	
	No	49	4,111	47	2,477	44	2,383
	Yes	56	521	65	340	49	366
Currently Breastfeeding		NS		**		**	
	No	50	3,079	47	1,827	47	1,638
	Yes	50	1,553	52	990	42	1,111
Smoking habit		*		NS		NS	
	No	50	4,525	49	2,657	45	2,703
	Yes	62	107	50	160	43	46
Total sample		49	4,632	48	2,817	43	2,749

***: p<0.01 ** : p<0.05 *:p<0.1;NS: Not significant

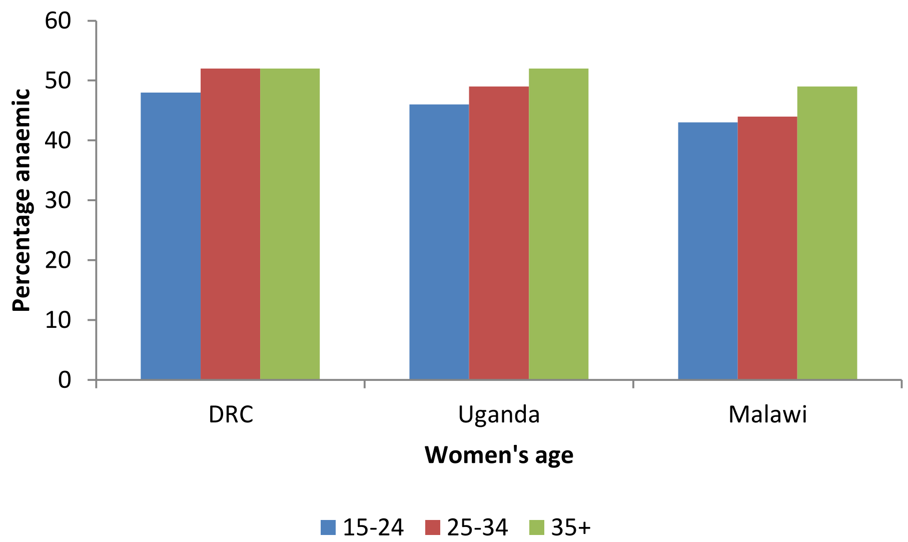
The data presented in Table 6.1 suggest that in addition to many other factors that might influence anaemia such as an appropriate diet, women's age and BMI are common individual factors associated with anaemia in women in all three countries. Anaemia in women increases with a decreased BMI and with an increased age as depicted in Figures 6.2 and 6.3.

Figure 6.2. Percentage of anaemic women by BMI and by country



Interestingly, older women in all three countries, those aged 35 and over are associated with higher prevalence of anaemia.

Figure 6.3. Percentages of anaemic women by age and by country



Pregnancy and high parity are among other individual factors that are found to be related with high prevalence of anaemia in women in DRC and Uganda. These findings are as one could expect. However, there were no significant differences between the prevalence of anaemia in women and whether they were pregnant or depending on the woman's parity in Malawi. Anaemia in women in DRC and Uganda varies significantly by women's parity. In Uganda, the prevalence of anaemia increases with women's parity.

Breastfeeding is another individual level factor associated with anaemia in women and is statistically significant in Uganda and Malawi but not in DRC. In Uganda, the results are as one would expect them to be; anaemia is much more prevalent among women who are breastfeeding. It has been suggested that lactating mothers are more likely to become anaemic (Allen 2005). This could be explained in two ways. First, women who are currently breastfeeding are more likely to have depleted their iron stores by the end of their pregnancy and may have lost a large amount of blood during childbirth (Latulippe, Irurita et al. 1999). Second, lactating women secrete a large amount of nutrients including iron in their breast milk. Although women have the ability to produce a sufficient quantity and quality of breast milk, breastfeeding women do need an increased amount of nutrients to maintain a reasonable level of iron (Picciano, Villalpando et al. 1998; Latulippe, Irurita et al. 1999). Surprisingly, in Malawi lactating women are associated with a decreased prevalence of anaemia. Anaemia is much more prevalent among women who smoke in DRC but not in Uganda and Malawi. However, women's age at first birth was not found to be related with anaemia in the three countries.

Table 6.2. presents potential socioeconomic factors that might be associated with anaemia in women at household level. The data suggest that the partner's level of education and having electricity are common risk factors associated with anaemia in women in these countries at household level.

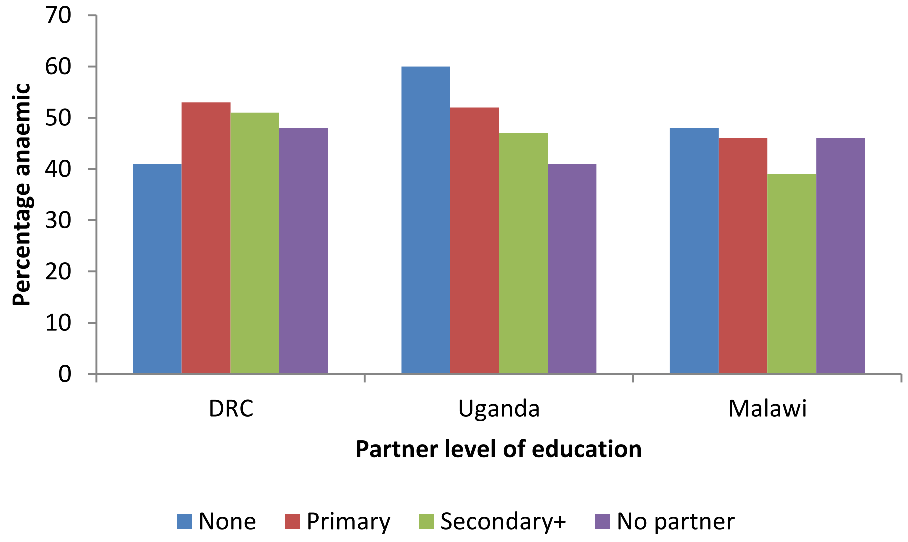
Table 6.2. Socioeconomic factors related with anaemia in women by country at household level

Variable	Category	DRC		Uganda		Malawi	
		%	Sample	%	Sample	%	Sample
Education		NS		***		*	
	None	50	1,008	55	587	47	643
	Primary	50	1,793	49	1,628	45	1,718
	Secondary+	50	1,831	42	602	41	388
Occupation		**		***		NS	
	Not working	48	1562	39	382	45	1,112
	Professional & Tech	43	104	38	74	44	36
	Clerical & sales	69	16	47	231	39	320
	Agriculture	52	1953	53	1,845	46	1,179
	Household/domestic	-	-	36	33	59	22
	Services	49	997	42	248	42	73
	Others	-	-	50	4	71	7
Marital status		NS		***		NS	
	Never married	48	1,090	39	639	45	416
	Married	50	3,125	52	1,833	44	2,009
	Widowed/separated	52	417	53	345	49	324
Partner education		***		**		**	
	None	41	380	60	235	48	342
	Primary	53	894	52	1,225	46	1,455
	Secondary+	51	2,101	47	624	39	517
	No Partner	48	1,257	41	733	46	435
Bed net use		NS		NS		NS	
	No	50	3,922	48	2,398	45	2,111
	Yes	52	710	52	419	43	638
Wealth status		*		NS		NS	
	Poorest	51	780	47	555	47	398
	Poorer	47	929	49	432	45	565
	Middle	49	872	51	579	45	567
	Richer	53	985	50	637	43	717
	Richest	50	1,026	46	601	45	493
Electricity		**		***		*	
	No	49	3,566	51	2,385	46	2,520
	Yes	54	986	36	264	37	175
	Not de jure	51	71	38	165	40	53
Total sample		**49**	**4,632**	**48**	**2,817**	**43**	**2,749**

***: p<0.01 ** : p<0.05 *:p<0.1;NS: Not significant

Apart from women in DRC, which is an outlier, the prevalence of anaemia decreases with an increased partner's level of education in Uganda and Malawi as one could expect (see Figure 6.4).

Figure 6.4. The prevalence of anaemia in women by partner's level of education by country



Women's level of education is related to anaemia in Uganda and Malawi but not in DRC. In Malawi and Uganda, those women with at least secondary level of education are associated with lower prevalence of anaemia compared with non-educated women. This is as argued in some studies that the more educated a women is the more value she places on good health (Desai 2000). Also, those better educated women are more likely to marry wealthier men or because of their own increased earnings (Dirige, Oglesby et al. 1991; Desai 2000; Gurung 2010). Therefore their diet will be better.

The place of residence is the only common community level factor which is found to be significantly associated with anaemia in women in these three countries. Anaemia is much more prevalent in rural areas than it is in urban areas (see Table 6.3). The source of drinking water is found to be related to anaemia in Uganda, but not in DRC and Malawi. The prevalence of anaemia is lower among those women who drink from piped water than it is from those who drink from other sources in all three countries although it is only significantly different in Uganda. The use of unclean water sources is associated with an increased risk of bone marrow diseases, other diarrhoeal diseases and hookworms which in turn are associated with an increased risk of anaemia; as suggested in the literature, improved water can protect people (Morris and Zidenberg-Cherr 1999; McCann and Ames 2007).

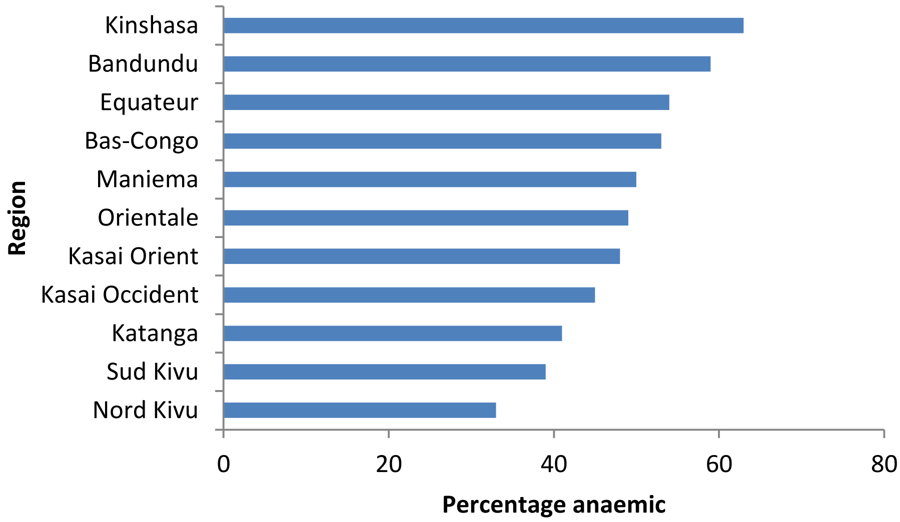
Table 6.3. Community level factors of anaemia in women by country

Variable	**Category**	**DRC**		**Uganda**		**Malawi**	
		%	**Sample**	**%**	**Sample**	**%**	**Sample**
Place of residence		**		***		**	
	Rural	51	2,424	52	2,370	46	2,391
	Urban	48	2,208	34	447	39	358
Water source		NS		***		NS	
	Piped/Tap	49	1,488	38	426	42	452
	Wells/Spring	50	2,490	52	1,886	46	2,219
	Others	53	654	46	505	36	78
Region		***		***		NS	
Total sample			**4,632**		**2,817**		**2,749**

***: p<0.01 ** : p<0.05 *:p<0.1

The prevalence of anaemia in women in DRC and Uganda does differ significantly between regions. Surprisingly in DRC, anaemia is two times more prevalent among women living in the capital city, Kinshasa, than it is among those from North Kivu region (see Figure 6.5). This might reflect the impact of current trends and a caution regarding urban growth in less developed countries in general and in Kinshasa in particular. It is argued that Kinshasa holds the status of the second largest city in Sub-Saharan Africa and the third largest city in the whole continent after Lagos and Cairo (Andrey 1983; Outeirino Hernanz, Outeirino Perez et al. 1994). With economic situations in countries such as in DRC where 80% of the population live below US$ 2 per day and a setting in which chronic crisis persists (civil war), with ongoing high inflation and poor economic performance, most urban citizens are unemployed. These results could be suggesting that the existing nutritional status in over populated cities such as Kinshasa is not good. This will be checked in multivariable analysis when the effect of many other factors is accounted for. However, the data suggest that the prevalence of anaemia does not differ between regions in Malawi.

Figure 6.5. The prevalence of anaemia among women in DRC by region



In Uganda, anaemia is much more prevalent in the North region than it is among those women from the capital city Kampala; see Figure 6.6. The data however, suggest that there is no significant regional difference (p-value=0.687) in the prevalence of anaemia among women in Malawi; see Figure 6.7.

Figure 6.6. The prevalence of anaemia among women in Uganda by region

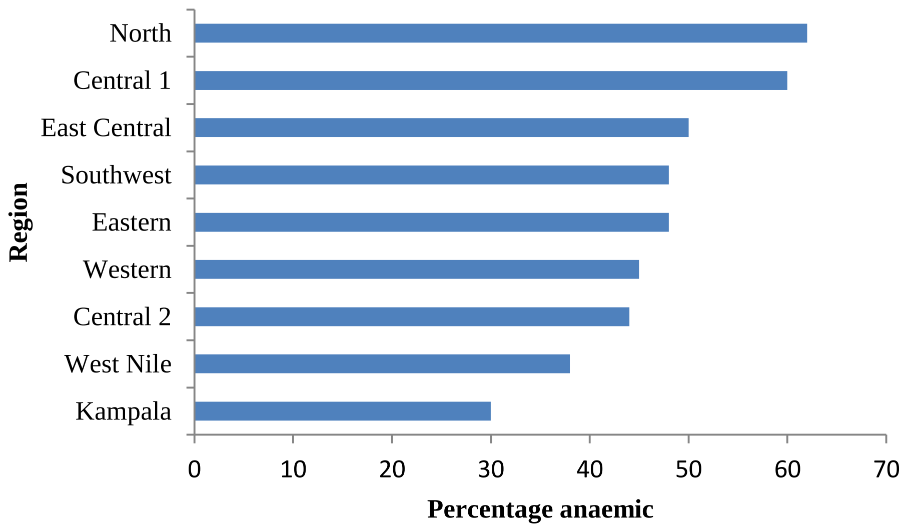
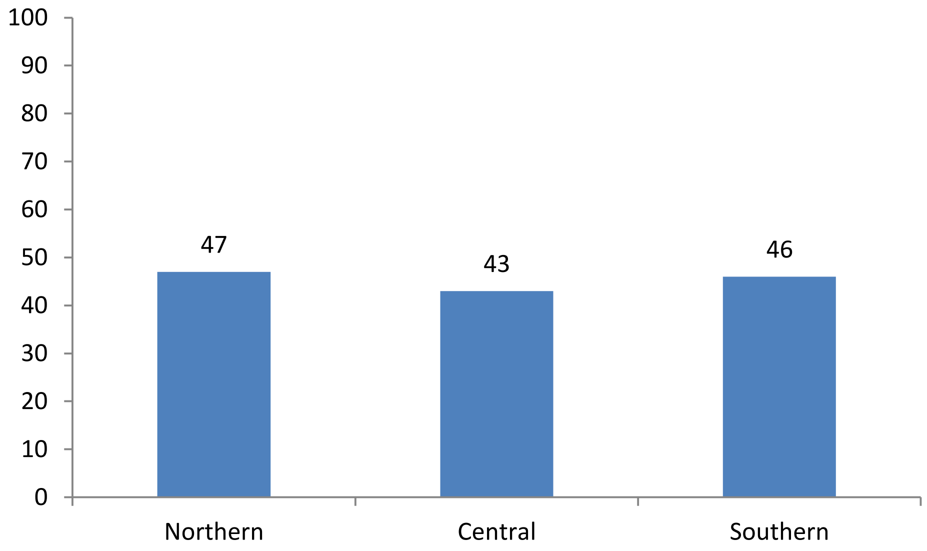


Figure 6.7. The prevalence of anaemia among women in Malawi by region



The results described above are based on the bivariate analysis. However, the next section uses multivariable analysis to account for the effect of other factors and explore further these findings.

6.3. Socioeconomic and demographic risk factors of anaemia in women

Multilevel logistic regression models were used to account for data structure and to investigate the association between the selected potential socioeconomic and demographic risk factors, and anaemia among women in the three countries. Four models were fitted at first. Three models for each country separately and one model pooling all the countries data together. In the model with all three countries together, a country variable was included to test the cross country interaction. Forward model selection was used for the model specification. All factors were tested one after the other to see if they were significant after controlling for the effect of other variables. Variables that were still significant at least in one country are included in all models to control for their effects and also for cross country comparison. The Wald test was used to test the joint significance for each of the selected categorical variable. Adjusted odds ratios and their associated 95% confidence intervals were also computed and are presented in Table 6.4 to

6.6. Variability in women's risk of having anaemia that could not be explained by the observed socioeconomic and demographic factors included in the models were tested and computed by including random effects in the models, taking into account three levels, individual women, household and community. The model assumptions of normality were tested using residual plots. The results suggest that the residuals are normally distributed for all four models; see Appendix 6.1. Further models were fitted including interaction terms. Cross-country comparisons are made. Similarities and differences are further discussed where appropriate.

Tables 6.4 to 6.6 present adjusted odds ratios and their associated 95% confidence intervals for the selected individual, household and community risk factors of anaemia in women by country. The results suggest that women's parity, BMI, breastfeeding and pregnancy are individual level factors associated with anaemia among women at least in one country. As argued elsewhere, pregnant women are more likely to have anaemia compared with their counterparts who are not pregnant in all three countries although not statistically significant in Malawi (Jamison and Mosley 1991; Olusanya, Luxon et al. 2004). Pregnant women from Uganda are associated with a twofold increased risk of anaemia. Whereas women in DRC have 32% increased risk of having anaemia (see Table 6.4).

Women's risk of having anaemia varies significantly with their BMI in DRC and Uganda but was not significant in Malawi. The results suggest that women's risk of having anaemia increases with a decreased BMI as depicted in Figure 6.8. Anaemia in women of childbearing age has been argued to be associated with weight loss. This emphasises the important role that nutrition plays on maternal health as documented elsewhere (Knouse 1977).

Figure 6.8. Women's risk of having anaemia by BMI and by country

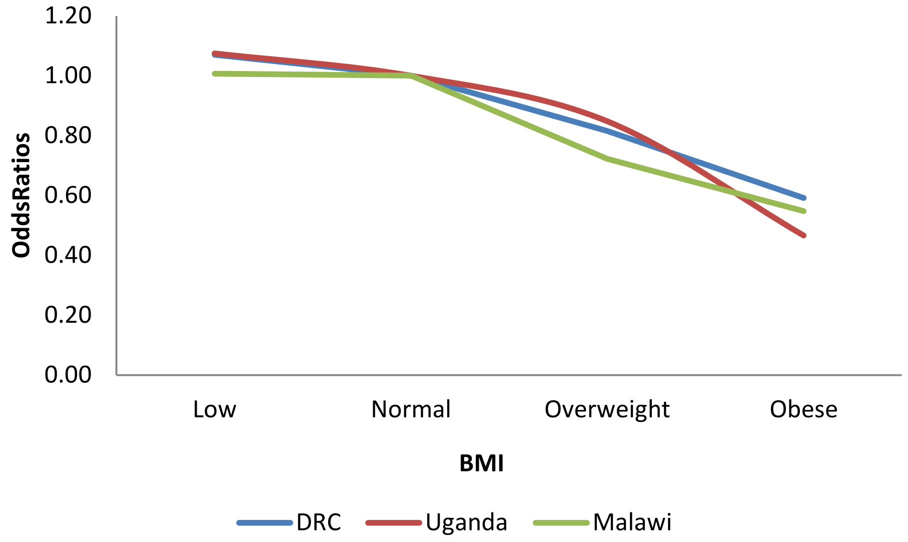


Table 6.4. Adjusted Odds Ratios and 95% confidence interval of anaemia in women by county

Variable	**Category**	**DRC**			**Uganda**			**Malawi**			**All**		
		O.R	**95% C.I**		**O.R**	**95% C.I**		**O.R**	**95% C.I**		**O.R**	**95% C.I**	
Current age													
	15-24	1.00			1.00			1.00			1.00		
	25-34	1.13	0.96	1.40	0.89	0.68	1.17	1.28	0.99	1.65	1.08	0.92	1.25
	35+	**1.23**	1.03	1.48	1.06	0.75	1.51	1.38	0.98	1.95	1.19	0.97	1.46
Parity													
	Zero	1.00			1.00			1.00			1.00		
	One	**1.23**	1.01	1.50	0.95	0.74	1.23	1.06	0.84	1.35	1.13	0.97	1.32
	Two	1.20	0.94	1.53	0.82	0.60	1.13	1.01	0.74	1.38	1.06	0.87	1.28
	Three+	1.22	0.86	1.73	0.90	0.58	1.40	1.01	0.59	1.73	1.10	0.83	1.44
BMI													
	Normal	1.00			1.00			1.00			1.00		
	Low	1.07	0.93	1.23	1.07	0.89	1.30	1.01	0.83	1.22	**1.12**	1.00	1.25
	Overweight	0.82	0.65	1.02	0.85	0.65	1.10	**0.72**	0.55	0.94	**0.82**	0.89	0.97
	Obese	**0.59**	0.39	0.91	**0.47**	0.27	0.79	**0.55**	0.32	0.94	**0.51**	0.37	0.71
Pregnancy													
	No	1.00			1.00			1.00			1.00		
	Yes	**1.32**	1.05	1.64	**2.31**	1.73	3.08	1.14	0.88	1.49	**1.63**	1.37	1.94
Currently breastfeeding													
	No	1.00			1.00			1.00			1.00		
	Yes	0.96	0.79	1.17	**1.38**	1.08	1.77	0.84	0.66	1.06	1.09	0.94	1.27

Figures in bold indicate statistically significant; O.R: Odds ratio; C.I: Confidence intervals

The results also suggest that after controlling for other observed risk factors of anaemia, women's occupation and marital status are factors associated with anaemia among women in Malawi and Uganda. However, education, household wealth status and electricity facility, which were statistically significant in the previous section (bivariate analysis), are not any more significant (see Table 6.5). Women who work in clerical and sales are associated with lower odds of anaemia only in Malawi. One could expect that those working in the agriculture sector to be less likely to have anaemia because of their direct involvement in food production and distribution. However, the results suggest that working in agriculture or other sectors make no difference (statistically) in DRC and Uganda. The results also suggest that widowed/separated women have 65% increased odds of becoming anaemic in Uganda.

Table 6.5. Adjusted Odds ratios of anaemia among women for socioeconomic factors at household level by country

Variable	Category	DRC			Uganda			Malawi			All		
		O.R	95% C.I		O.R	95% C.I		O.R	95% C.I		O.R	95% C.I	
Education													
	None	1.00			1.00			1.00			1.00		
	Primary	0.91	0.76	1.08	0.93	0.74	1.16	0.96	0.78	1.18	0.91	0.79	1.04
	Secondary+	0.84	0.68	1.05	1.12	0.82	1.53	0.87	0.63	1.22	0.96	0.80	1.13
Occupation													
	Not working	1.00			1.00			1.00			1.00		
	Professional & Tech	1.03	0.66	1.61	0.75	0.42	1.35	1.07	0.51	2.25	0.89	0.63	1.25
	Clerical & sales	2.30	0.70	7.54	1.19	0.82	1.74	**0.76**	0.58	0.99	1.11	0.82	1.51
	Agriculture	1.04	0.86	1.27	1.14	0.85	1.54	0.95	0.79	1.15	1.08	0.93	1.27
	Household/domestic	1.00	1.00	1.00	1.03	0.44	2.40	1.87	0.76	4.58	0.73	0.33	1.62
	Services	0.93	0.78	1.12	1.01	0.69	1.46	0.88	0.53	1.47	0.96	0.81	1.13
	Others	1.00	1.00	1.00	2.23	0.26	18.96	6.79	0.74	62.47	1.84	0.23	14.38
Marital status													
	Never married	1.00			1.00			1.00			1.00		
	Married	0.95	0.76	1.19	1.27	0.94	1.71	0.97	0.71	1.31	1.02	0.86	1.23
	Widowed/separated	1.05	0.78	1.41	**1.65**	1.15	2.37	1.20	0.83	1.73	1.20	0.96	1.50
Wealth status													
	Middle	1.00			1.00			1.00			1.00		
	Poorest	1.03	0.82	1.29	0.98	0.75	1.29	1.03	0.78	1.36	0.98	0.82	1.16
	Poorer	0.97	0.78	1.19	1.08	0.82	1.43	0.98	0.77	1.26	0.99	0.84	1.18
	Richer	1.01	0.81	1.25	0.98	0.76	1.26	0.99	0.78	1.25	1.04	0.88	1.22
	Richest	0.81	0.64	1.03	1.01	0.76	1.36	1.14	0.86	1.52	0.89	0.74	1.07
Electricity													
	No	1.00			1.00			1.00			1.00		
	Yes	1.13	0.86	1.50	0.91	0.60	1.36	0.77	0.49	1.12	1.20	0.96	1.50
	Not dejure	1.06	0.63	1.77	0.74	0.52	1.05	0.83	0.46	1.49	0.83	0.62	1.11

Figures in bold indicate statistically significant; O.R: Odds ratio; C.I: Confidence intervals

Table 6.6. Adjusted Odds ratios of anaemia among women for community level factors by country

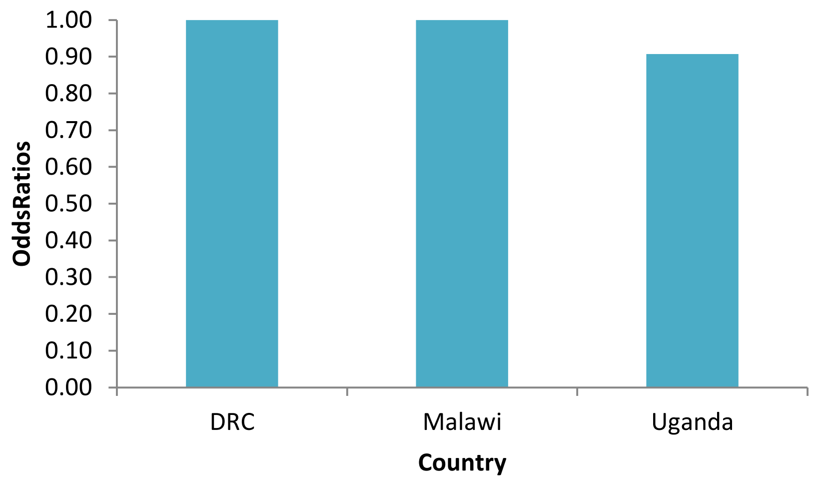
Variable	**Category**	**DRC**			**Uganda**			**Malawi**			**All**		
		O.R	**95% C.I**		**O.R**	**95% C.I**		**O.R**	**95% C.I**		**O.R**	**95% C.I**	
Place of residence													
	Urban	1.00			1.00			1.00			1.00		
	Rural	**1.49**	1.18	1.90	**1.53**	1.00	2.35	1.24	0.90	1.71	**1.40**	1.14	1.71
Water source													
	Piped/Tape	1.00			1.00			1.00			1.00		
	Wells/Spring	0.95	0.73	1.25	1.14	0.83	1.58	1.09	0.83	1.58	0.97	0.83	1.58
	Others	1.11	0.78	1.57	1.06	0.72	1.57	1.03	0.72	1.57	1.09	0.72	1.57
Country													
	DRC	-			-			-			1.00		
	Malawi	-	-	-	-	-	-	-	-	-	1.00	0.96	1.03
	Uganda	-	-	-	-	-	-	-	-	-	0.91	0.78	1.06

Figures in bold indicate statistically significant; O.R: Odds ratio; C.I: Confidence intervals

The results for the modelling suggest that after controlling for well known risk factors of anaemia in women such as pregnancy and BMI, the place of residence is an important community level factor associated with anaemia among women in DRC and Uganda. Women living in rural areas are associated with an increased risk of having anaemia than their counterparts who live in urban areas. The region of residence is among many other factors related with anaemia in women in DRC and Uganda but not in Malawi.

A country variable was created in order to check whether differences suggested between countries are significant. A multilevel logistic regression model was fitted with all the data from all countries combined. The results suggest that although women from Uganda were associated with a 9% decreased risk of having anaemia compared with those from DRC (O.R; 95% C.I: 0.91; 0.78-1.06) and Malawi (O.R; 95% C.I: 1; 0.0.96-1.03) as depicted in Table 6.6., this was not statistically significant (Figure 6.9).

Figure 6.9. A graph depicting women’s risk of having anaemia by country



6.3.1. Multilevel logistic regression model

As stated in the introduction, multilevel logistic regression models were used to account for the hierarchical nature of the data and most importantly to quantify unexplained differences in women’s risk of having anaemia which might be due to unobserved factors. Such factors could be social, administrative, operating at household and community levels. The results suggest that after controlling for observed social risk factors of anaemia in women there are still significant unexplained differences in women's risk of having anaemia which might be due to unobserved community factors in all the three countries. The variance components are presented in Table 6.7. The unobserved factors could include traditional beliefs, and cultural norms and behavioural factors. There is much heterogeneity in these three countries. For example in DRC there are as many as 250 ethnic groups, with about 700 local languages and dialect spoken. As there were no significant differences in women's risk of having anaemia at the household level in all the three countries, random effects at the household level were removed. Table 6.7 presents unexplained differences in women's risk of having anaemia for community level.

Table 6.7. Unexplained differences in women's risk of having anaemia by level and country

	DRC		Uganda		Malawi	
Level	Variance	SE	Variance	SE	Variance	SE
Community	**0.266*** **	0.050	**0.273*** **	0.063	**0.173*** **	0.057

***: p<0.01 ** : p<0.05 *:p<0.1

6.3.2. Model assumption and diagnostics

The model assumptions of normally distributed errors were checked to ensure that underlying assumption of normality and constant variance are met and that the models fit well the data. Normality was checked through the plotting of the residuals using quantile-quantile plots. The results suggest that the residuals are normally distributed for all four models (see Appendix 6.1.).

6.4. Country specific models

A separate country specific model, including only significant variables with interaction terms, was also fitted and the results are presented in Table 6.8, 6.9 and 6.10. Country specific models were fitted to check whether there is diversity in covariates significance in each specific country. Country specific models were fitted with only factors that are significantly associated with anaemia in that country and the results are presented in Tables 6.8, 6.9 and 6.10. Interaction terms were also tested where possible. Differences and similarities between countries are further discussed.

Table 6.8 presents the odds ratio and 95% confidence intervals for DRC specific model. It shows that the risk of anaemia among women from DRC varies by age, parity, BMI, pregnancy, the place of residence and by region. This finding is true even when the effects of socioeconomic factors such as education, occupation and household wealth status are controlled for (see previous section). The interaction term was tested to see whether high risk of anaemia suggested among pregnant women significantly differ by age group. The interaction terms were created between pregnancy and age and included in the model. The results, however, suggest that a high risk of anaemia associated with pregnancy does not differ by women's ages.

Table 6.8. Country specific model for DRC

Variable	Category	OR	95% CI	
Current age	15-24	1.00		
	25-34	1.15	0.98	1.35
	35+	**1.25**	1.07	1.46
Parity	Zero	1.00		
	One	**1.20**	1.03	1.40
	Two	1.14	0.97	1.34
	Three+	1.20	0.92	1.56
BMI	Low	1.00		
	Normal	0.92	0.80	1.05
	Overweight	**0.74**	0.60	0.93
	Obese	**0.50**	0.33	0.76
Pregnancy	No	1.00		
	Yes	**1.44**	1.09	1.91
Residence	Rural	1.00		
	Urban	**0.70**	0.61	0.80
Region	Kinshasa	1.00		
	Bas-Congo	**0.53**	0.40	0.71
	Bandundu	**0.64**	0.49	0.83
	Equateur	**0.54**	0.41	0.71
	Orientale	**0.45**	0.34	0.60
	Nord Kivu	**0.25**	0.18	0.33
	Maniema	**0.48**	0.37	0.63
	Sud Kivu	**0.26**	0.20	0.35
	Katanga	**0.33**	0.26	0.43
	Kasai Orient	**0.43**	0.32	0.56
	Kasai Occident	**0.37**	0.28	0.49

Figures in bold indicate statistically significant, O.R: Odds ratio; C.I: Confidence intervals

Factors associated with anaemia in women from Uganda are BMI, marital status, pregnancy, breastfeeding, the place of residence and the region (Table 6.9). Age was left in the model to control for confounding effect of age. An interaction term was created between pregnancy and marital status. The results indicate that high risk of anaemia observed among pregnant women significantly differs whether they are married, divorced/separated or have never married. Pregnant women who are widowed/separated are 7 times more likely to be anaemic compared with their counterparts who have never married. In countries with limited resources, such as in Uganda, with no social support, it could be a challenging task for single mothers to get necessary nutrients.

Table 6.9. Country specific model for Uganda

Variable	Category	OR	95% CI	
Current age	15-24	1.00		
	25-34	0.92	0.75	1.14
	35+	1.10	0.87	1.39
BMI	Low	1.00		
	Normal	0.93	0.78	1.12
	Overweight	0.79	0.60	1.04
	Obese	**0.45**	0.27	0.75
Marital status	Never married	1.00		
	Married	**1.32**	1.02	1.72
	Widowed	**1.63**	1.19	2.25
Pregnancy	No	1.00		
	Yes	**8.60**	2.92	12.29
Breastfeeding	No	1.00		
	Yes	**1.24**	1.02	1.50
Pregnancy vs marital status	Pregnant & never married	1.00		
	Pregnant & married	**0.22**	0.07	0.66
	Pregnant widowed/ div	0.50	0.32	2.30
Residence	Rural	1.00		
	Urban	**0.67**	0.49	0.92
Region	Central 1	1.00		
	Central 2	**0.54**	0.38	0.77
	Kampala	**0.51**	0.32	0.81
	East Central	**0.64**	0.46	0.89
	Eastern	**0.59**	0.42	0.83
	North	0.99	0.73	1.35
	West Nile	**0.41**	0.29	0.59
	Western	**0.52**	0.37	0.72
	Southwest	**0.62**	0.45	0.87

Figures in bold indicate statistically significant, O.R: Odds ratio; C.I: Confidence intervals

The results, however, suggest that in Malawi women's risk of anaemia does not significantly differ whether they are pregnant or not. This is possibly due to few (366) pregnant women. The age, BMI, partner's level of education, breastfeeding and region are among many other known factors that interfere with women's risk of having anaemia. Women from central region are less likely to have anaemia than those from Northern or Southern regions (Table 6.10). Older women are associated with an increased risk of anaemia.

Table 6.10. Country specific model for Malawi

Variable	Category	OR	95% CI	
Current age	15-24	1.00		
	25-34	1.14	0.94	1.38
	35+	**1.28**	1.03	1.58
BMI	Low	1.00		
	Normal	1.01	0.84	1.21
	Overweight	**0.71**	0.53	0.94
	Obese	**0.52**	0.31	0.89
Partner's education	None	1.00		
	Primary	0.98	0.77	1.24
	Secondary +	**0.71**	0.53	0.95
	No partner	0.89	0.64	1.24
Breastfeeding	No	1.00		
	Yes	**0.81**	0.69	0.96
Region	Northern	1.00		
	Central	**0.78**	0.62	0.99
	Southern	0.89	0.71	1.11

Figures in bold indicate statistically significant, O.R: Odds ratio; C.I: Confidence intervals

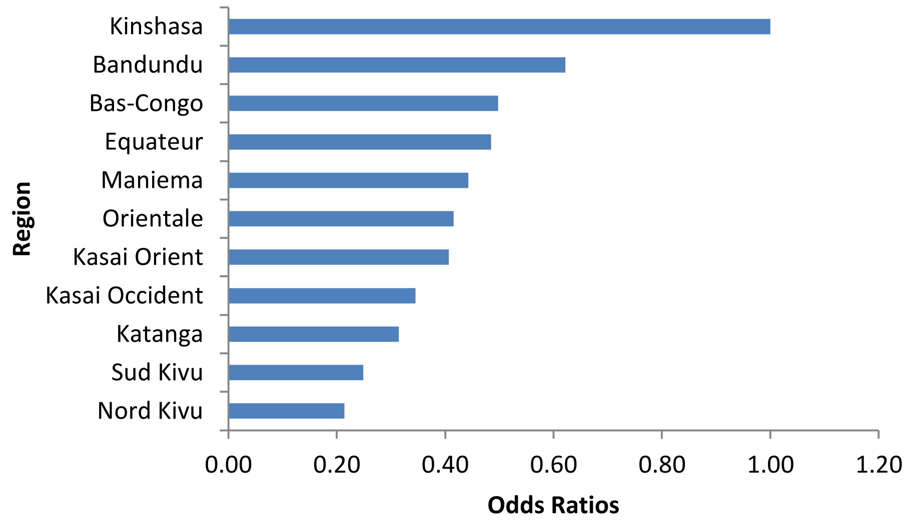
Since the results suggest that pregnant women are more likely to have anaemia than non-pregnant women, the samples for each country were split into two (pregnant and non-pregnant women and different multivariable logistics regression models were fitted to explore further socioeconomic and demographic factors associated with anaemia among pregnant and non-pregnant women (Appendix 6.2 & 6.3). The results suggest that besides many other known factors associated parity, the place of residence and the region are found to be associated with anaemia in pregnant women in DRC. Age, BMI, women's and their partner's education, household wealth, the place of residence is related with anaemia among non-pregnant women in DRC. None of the selected socioeconomic and demographic factors were found to be related with anaemia in pregnant women in Uganda and Malawi. However, the results indicate that for those women who are not pregnant, BMI, breastfeeding, marital status, the place of residence and region are factors influencing women's risk of having anaemia in Uganda. While age, BMI and partner level of education are found to be related with women's risk of anaemia in Malawi.

Country specific models suggest that the region of residence is among many other factors related with anaemia in women in DRC, Uganda and Malawi (Figures 6.9; 6.10 & 6.11). The results suggest that in DRC, those women who live in the capital city, Kinshasa and others regions near Kinshasa, such as Bandundu, Bas-Congo and Equateur are at higher risk of having anaemia compared with those women who live in regions that are far away from Kinshasa (see Figure 6.9). This could be attributed to many factors including high urban population growth, the annexation and reclassification of land around the periphery of Kinshasa as urban and rural-urban migration to name just a few (Cohen 2004).

There is a growing concern with the issues of population distribution in less developed countries. Concentrated population in urban areas is argued to be a result of accelerated rural-urban migration. In least developed countries, rural migrants move to cities with the expectation of economic and social betterment (Lanjouw and Lanjouw 2001). However, migration streams to urban areas, which are among the main factor of population growth in cities, are generally composed of disadvantaged families. As argued elsewhere, these families may have a harder time coping in urban areas than in rural areas (Engstrom, Castro et al. 2008). The extreme unsanitary and congested conditions which prevail in some cities to such extent that epidemics and outbreak diseases like cholera are common, and often endure for extended period, causing chronic malnutrition, ill-health and mortality (Davis 2006; Riley, Ko et al. 2007). In most of the cases, rural-urban migrants end up unemployed and in slums areas in cities, where they are exposed to malnutrition and anaemia (Davis 2006). Repeated conflicts in DRC are among many other factors that are contributing to an increased urban population. People fleeing conflict zone move to cities for security reasons (Raleigh and Hegre 2009).

This challenges the common assumption that the economic conditions and health of urban populations are better to those of rural dwellers. Indeed, this chapter (Figure 6.10) suggest that in some countries such as DRC, the urban poor exhibit poorer nutritional outcomes than those in rural areas. Urban population growth is not only associated with demographic issues but also with health issues as suggested elsewhere (Brabin, Premji et al. 2001; Melo, Purini et al. 2002). Adjusted odd ratios presented in figure 6.10 were obtained using country specific model.

Figure 6.10. A graph depicting the adjusted Odds ratios for anaemia in women in DRC by region



In Uganda however, women living in the capital city Kampala are associated with a decreased risk of having anaemia compared with those women who live in other regions as suggested in section two and as presented in Figure 6.11. In comparison to women from Kampala, those women from Kinshasa have a higher risk of having anaemia. The difference found in women's risk of having anaemia between the capital cities of Uganda and DRC is not surprising.

The DRC is emerging from nearly a decade of civil war and ethnic strife that has disrupted civil society, destroyed the weakened infrastructure and has decimated the country's standard of living (Behets, Matendo et al. 2006). Most displaced people go to Kinshasa, the capital city. One would expect food security in Kinshasa because food produced in all other regions could be found in Kinshasa. However, during civil war Kinshasa is cut off from it supply routes from other regions, with virtually no all-weather roads (Behets, Matendo et al. 2006). One often hears reports of prevailing hunger and malnutrition in the city, with families only eating once a day or every other day (Puechguirbal 2003). The food security situation in Kinshasa is worse than one could imagine and might partially explain the higher prevalence of anaemia found in Kinshasa (Rossi, Hoerz et al. 2006).

Figure 6.11. A graph showing adjusted odds ratios for anaemia in women in Uganda by region

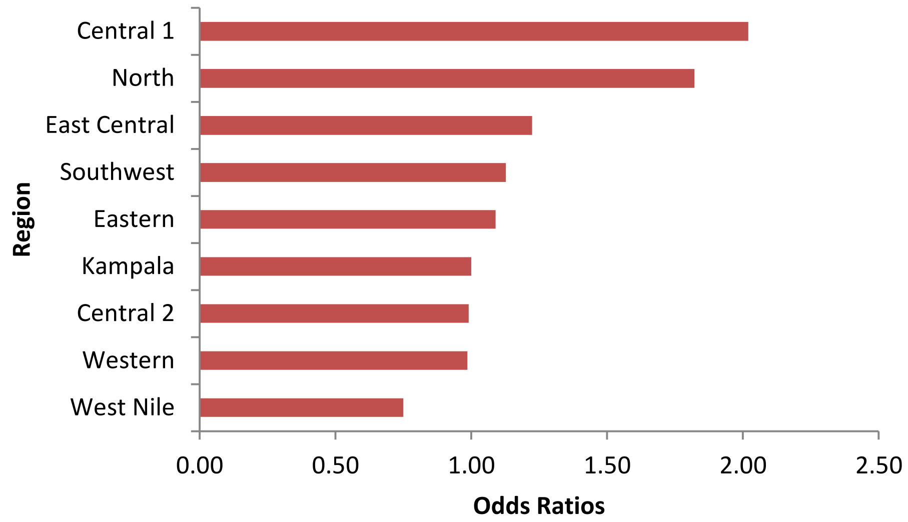
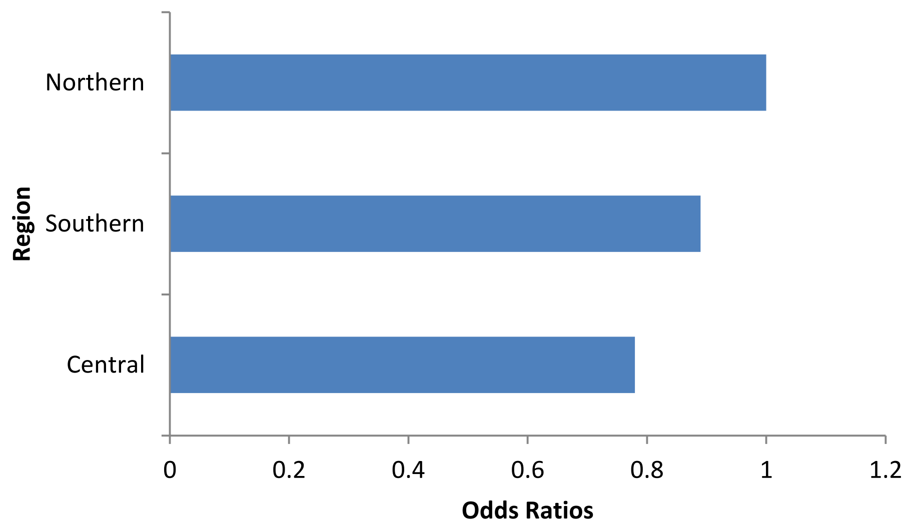


Figure 6.12. A graph showing adjusted odds ratios for anaemia in women in Malawi by region (obtained from country specific model)



6.5. Similarities and differences between countries

Although the country interaction term included in the model in Table 6.6 suggested that differences in women's risk of having anaemia observed between countries are not statistically significant, the results indicate that factors that are associated with the risk of anaemia among women are not the same in all three countries (Tables 6.8; 6.9 and 6.10). Age is found to be related with anaemia in DRC and Malawi but not in Uganda. The risk of anaemia during child bearing age increases with an increased age in DRC and Malawi. Parity is only significant in DRC but not in Malawi and Uganda. Breastfeeding is associated with women's risk of having anaemia in Uganda and Malawi but not in DRC. Marital status is a risk factor of anaemia in Uganda but not significant in DRC and Malawi. In all three countries, the results however, suggest that BMI is an important factor associated with anaemia among women and that the risk of being anaemic decreases with an increased BMI. In addition there are important regional differences in women's risk of having anaemia within all three countries. This could be due to other factors including climatic and environmental conditions which might not be the same across regions within countries.

6.6. Common socioeconomic and demographic risk factors of anaemia in children and women.

The results from both Chapters 4 and 6 suggest that for maternal, household and community factors that were considered for both children and women, region is a common risk factor associated with anaemia in both children and women.

Table 6.11. Common risk factors of anaemia among children and women by country

Variable	DRC		Uganda		Malawi	
	Children	Women	Children	Women	Children	Women
Individual related factors						
Age	S	S	S	NS	S	S
Household related factors						
Bed net use	NS	NS	NS	NS	NS	NS
Maternal education	NS	NS	NS	NS	NS	NS
Wealth quintiles	S	NS	S	NS	S	NS
Community related factors						
Place of residence	NS	S	NS	S	NS	NS
Water source	NS	NS	S	NS	S	NS
Region	S	S	S	S	NS	NS
Maternal related factors						
Breastfeed/ breastfeeding	NS	NS	NS	S	NS	S

NS: means statistically not significant ; S: statistically significant

Although, when using bivariate methods, breastfeeding is suggested to be related with anaemia in children and women in all three countries, after controlling for the effect of factors such as drinking water and random effects it is significantly related only with women’s risk of having anaemia in Uganda and Malawi (non-pregnant women), but not statistically significant with women’s and children’s risk of anaemia in DRC (Table 6.11).

The source of drinking water is found to be associated with the risk of anaemia among children but not women. The results suggest that even after controlling for maternal anaemia status the source of drinking water is significantly related with children’s risk of having anaemia in Uganda and Malawi but not in DRC. Contrary to children, women’s risk of having anaemia does not differ significantly with the source of drinking water. Moreover, the region of residence is a risk factor associated with anaemia among both children and women in DRC and Uganda, but not in Malawi. Furthermore, the results suggest that unexplained variability in children’s and women’s risk of having anaemia is found at community level but not at household level. This could be because the average numbers of women per household ranged from 2 to 4 women.

6.7. Discussion

The contributions of this chapter can be explained in three ways. It contributes to understanding the prevalence and social risk factor of anaemia among women in DRC, Uganda and Malawi and common social risk factor associated with anaemia for both women and children. It contributes to research on the pattern of anaemia between the three countries. It also contributes to knowledge about differences in women's risk of having anaemia at household and community levels using a hierarchical modelling approach. Nearly half of women are anaemic in these three countries. Age, parity, BMI, partner's level of education, marital status, breastfeeding, pregnancy, the place of residence and region are factors that are found to be related with the risk of anaemia at least in one country. There is no significant difference in the prevalence of anaemia between the three countries. However, country specific models indicate that social risk factor associated with anaemia among women of child bearing age differ between the countries. With regard to age, the risk of anaemia increases with an increased age in all three countries, although the differences are not significant in Malawi. Women aged 35 and above are associated with an increased risk of anaemia compared with younger women. This could be partially explained by biological processes. It is argued that iron accumulation and loss must be at similar levels to maintain adequate body iron stores for women. The body iron store in women diminishes with the frequency of menstrual bleeding and pregnancy. If women are not accumulating more iron than what is lost they could become anaemic (Brockerhoff 1999). However, there is as yet little firm evidence on which to ground these suspicions and which to guide action. The other reason could be premenopausal women have lower levels of iron stores than younger women and if they do not increase iron intakes (from food rich in iron or iron supplements) they can easily become anaemic (Annibale, Lahner et al. 2003).

Although all women of reproductive age need more iron stores, pregnant and breastfeeding women need extra iron because of physiological process. During pregnancy there are small and continuous physiologic adjustments which affect the metabolism of nutrients such as iron. It is for this reason that pregnant women who do not consume food rich in micronutrients such as iron or Vitamin A can easily be exposed to anaemia (King 2000). The risk of anaemia is significantly higher among women with low BMI in all three countries. Low BMI could reflect undernutrition or other chronic infections responsible for anaemia. Undernutrition has been argued to be strongly related with food insecurity which might be frequent in the three countries (Ritchie, Burgio et al. 1997).

Marital status is among many other social risk factors of anaemia among women in Uganda. Widowed/separated women (pregnant or not) are more likely to be anaemic than married women. Being widowed or separated can be a source of considerable stigma and other mental disorders such as stress which can easily affect women's eating habits (Kandiah, Yake et al. 2006). Stress has been argued to be strongly related with poor nutrition (Takeda, Terao et al. 2004). Stress influence appetite and comfort food preference responsible for lower food intake which might expose widowed and separated women to anaemia (Kandiah, Yake et al. 2006). Others infections such as HIV or TB could be among many other contributor factors to a higher risk of anaemia among widowed women if partners were infected. In areas with high prevalence of HIV, studies pertaining to anaemia and its related factors must therefore consider HIV status of the study participants (Matsuo, Saitoh et al. 1999).

Regional differences in women's risk of having anaemia are really apparent within these countries. In DRC, women living in the capital city, Kinshasa, are twice as likely to be anaemic compared with those living in other regions. There is reason to suspect that higher risk of anaemia in women from Kinshasa could partially be the results of the scale of expansion in urban population growth (mostly due to rural-urban migration and insecurity in other region of the country than natural increase). Political crisis in DRC has prevented the formal economy from reducing poverty and its correlates of hunger, diseases, and poor health which might increase the risk of anaemia (Guillet, Driss et al. 1998; Bird and Shepherd 2003). Food security is still frequent issue in Kinshasa (Roberts 2001).

In Malawi, women from the central region are associated with a decreased risk of anaemia compared with those from the Southern and Northern regions. Higher prevalence in the Southern region might reflect the severity of poverty in the Southern region as argued elsewhere (Huma, Salim-Ur-Rehman et al. 2007). Research conducted in previous years has suggested similar results; the prevalence of anaemia is higher in the Southern region compared with Central region (Van et.al. 2000; Rogerson et al. 2000). The results from this study also indicate that pregnant women are more likely to be anaemic than non-pregnant women the difference is not seen to be statistically significant in Malawi perhaps because of smaller sample sizes. There are in total 366 pregnant women and 2363 non-pregnant.

In Uganda, Central and Northern regions are associated with an increased risk of anaemia. In Uganda, as in Kinshasa, it is argued that most of the urban population are concentrated in the Central region where food prices are very high compared to other regions (Lokeshwar, Mehta et al. 2011). The Northern region is argued to be far behind other regions in term of poverty reduction (Lokeshwar, Mehta et al. 2011).

Significant random effects at community level in all three countries imply that individual level factors may not fully capture the entire risk of anaemia among women. Common risk factors between women and children support a call for a widening and focus nutritional programmes towards the broader context of women’s family and communities within the three countries. Plans and activities against anaemia among women within regions in DRC, Uganda and Malawi should be integrated into poverty reduction strategic plans.

6.8. Summary

The aims of this chapter were to investigate the prevalence and socioeconomic and demographic factors of anaemia among women of childbearing age from DRC, Uganda and Malawi. The chapter also aimed to quantify and explain where possible unobserved factors which might influence women's risk of having anaemia due to the household or community in which they live and explain common risk factors of anaemia for both women and children. The study suggests that anaemia is highly prevalent among women in these countries and nearly half of women of reproductive age are anaemic in DRC, Uganda and Malawi.

Bivariate analysis suggest the age, women's BMI and whether they are pregnant are the commonest individual risk factors associated with anaemia in women. Women's level of education and electricity facility are common household risk factors whereas the place of residence and the region are community related factors of anaemia in women. However, when the effect of all significant factors were accounted for the results suggest that BMI, pregnancy, the place of residence and region are important factors associated with women's risk of getting anaemia. Breastfeeding is associated with higher risk of anaemia for non-pregnant women. The results also suggest that a higher risk associated with pregnancy varies by marital status.

Age, place of residence and region are the commonest risk factors associated with anaemia in both children and women. Multilevel models indicate that there are significant unexplained variations in women and children's risk of having anaemia which are due to the communities in which women live in all the three countries. However, no significant differences were found at household levels. Also, the results suggest that women's risk of anaemia does not significantly differ between these three countries.

There are regional differences in women's risk of having anaemia within these countries. Plans and activities against anaemia among women within regions in DRC, Uganda and Malawi should integrate into poverty reduction strategic plans. In areas with high prevalence of anaemia, studies pertaining to anaemia and its related factors must therefore consider HIV status of the study participants.

CHAPTER 7
Changes in the prevalence of anaemia among women in Malawi

7.1. Introduction

Using the 2004 Malawi Demographic Health Survey, Chapter 6 investigated risk factors that are related with women's risk of anaemia in DRC, Uganda and Malawi. During the course of the writing of this thesis the 2010 Malawi DHS was released. This afforded the opportunity to study if the levels and determinants of anaemia have changed over time. This could be one of the first opportunities to do this comparison at a population level. This chapter provides a comprehensive review of the changes in the prevalence and risk factors of anaemia among women using Malawi Demographic and Health Surveys from both 2004 and 2010. The chapter aims to examine whether there are changes in the prevalence of anaemia among women in Malawi and discusses various factors that might have brought about the changes. It answers the following research questions:

1. *What is the trend in the prevalence of anaemia among women in Malawi and how does it differ by the selected characteristics over time?*
2. *What factors can be identified as contributing to changes in anaemia level amongst women in Malawi between 2004 and 2010?*

In this chapter, the prevalence of anaemia in women in 2004 and 2010 is described and compared. Data from the two surveys are later combined, a time interaction is computed and included in order to test for time effects. Socioeconomic and demographic characteristics of women and potential risk factors associated with haemoglobin levels are explored and further discussed.

There are four sections to the chapter. After the introduction, section two presents the descriptive statistics by year. This section aims to describe the prevalence of anaemia among women for each of the selected socioeconomic and demographic characteristics, compares and discusses changes over time and within groups. Section three discusses factors that might have brought about the changes in the prevalence of anaemia among women in Malawi, and section four combines both datasets, and includes a year variable to test for time effects and comment on potential risk factors associated with anaemia.

7.2. Descriptive statistics

In this section, changes in the prevalence of anaemia are explored between 2004 and 2010 and further discussed. The prevalence of anaemia among women in 2004 and 2010 surveys are discussed for each of the selected socioeconomic and demographic factors.

Overall the prevalence of anaemia has decreased to 29% in 2010, from 44% in 2004. A 15 percent point change in 6 years is a significant achievement. This decrease is statistically significant (percentage point change: 15; 95% C.I: 13 to 17). In 2010, the results suggest that anaemia is significantly related with most of the selected characteristics but not with women's occupation, smoking habit and bed net use. The decrease in the prevalence of anaemia among women between the two years is significant for almost all socioeconomic and demographic factors (Tables 7.1; 7.2 and 7.3).

Table 7.1 The prevalence of anaemia among women in Malawi by year

Variable	Category	Anaemia DHS 2004 %	Anaemia DHS 2004 Sample	Anaemia DHS 2010 %	Anaemia DHS 2010 Sample	Between year difference	95% C.I	
Current age		**		***				
	15-24	43	1203	29	3010	14	11	17
	25-34	44	864	27	2386	17	13	21
	35+	49	682	32	1894	17	13	21
Parity		NS		***				
	Zero	46	963	31	2918	15	11	19
	One	46	955	27	2554	19	15	23
	Two	42	740	29	1640	13	9	17
	Three+	41	91	26	178	15	2	5
BMI		**		***				
	Low	47	649	31	1684	16	12	20
	Normal	46	1695	30	4340	16	13	19
	Overweight	39	307	26	970	13	7	19
	Obese	31	72	23	296	8	-4	20
Pregnancy		NS		***				
	No	44	2383	28	6601	16	14	18
	Yes	49	366	39	689	10	4	16
Breastfeeding		**		***				
	No	47	1638	30	4857	17	14	20
	Yes	42	1111	27	2433	15	12	18
Smoking habit		NS		NS				
	No	45	2703	29	7213	16	14	18
	yes	43	46	36	77	7	-11	25
Total sample		**44**	**2749**	**29**	**7290**	**15**	**13**	**17**

***: p<0.01 **: p<0.05 *:p<0.1;NS: Not significant

For all age groups the prevalence of anaemia is lower in 2010 compared with 2004. By age group, the data indicate that the fall in the prevalence of anaemia is smaller (14 percent point change) among the youngest age group (15-24) than it is among the other age groups (17 for both older groups).

The prevalence of anaemia among women, however, decreases with an increased parity, BMI, level of education and household wealth status (Tables 7.1 and 7.2). Although there has been an 8 points reduction in anaemia level among women who are obese between 2004 and 2010, the fall in anaemia between the two years is significant in all categories of BMI except for those that are obese (percentage point change: 8; 95% C.I: -4 to 20). However, for almost all categories of other characteristics the prevalence of anaemia is significantly lower in 2010 compared with 2004. By levels of education and by household wealth, the data suggest that the fall in the prevalence of anaemia in 2010 is slightly higher among those women with at least primary education and among those women in the highest wealth quintile. Possible reasons are further investigated in Section 7.3. Anaemia prevalence among women in Malawi differs whether they are pregnant or not. Although the difference was not significant in 2004 (probably due to small sample size), pregnant women are associated with an increased risk of anaemia compared with non-pregnant women. Anaemia among pregnant women has decreased to 39% in 2010 from 49% in 2004. Possible reasons for lower prevalence of anaemia observed in 2010 for all women's characteristics are discussed in Section 7.3.

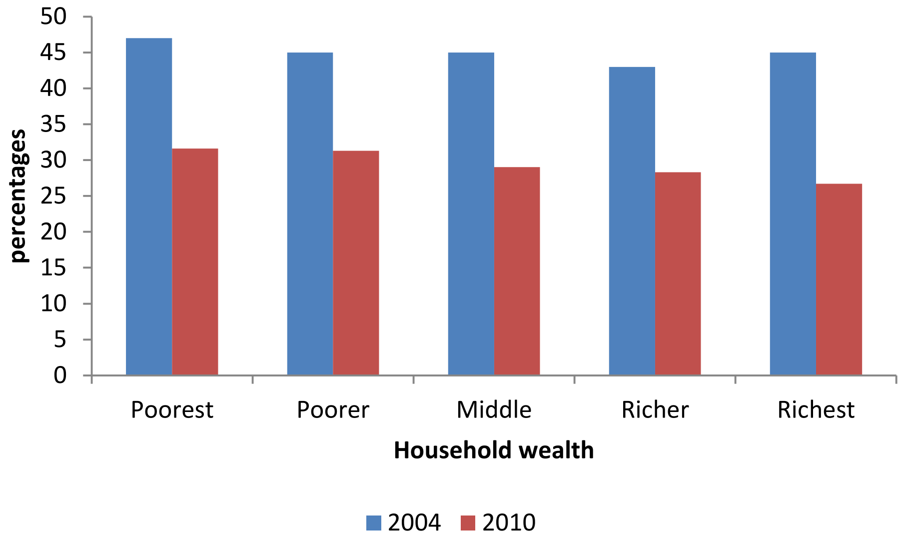
Table 7.2 The prevalence of anaemia among women by socioeconomic factor and by year

Variable	Category	Anaemia DHS 2004		Anaemia DHS 2010		% point difference	95% C.I	
		%	Sample	%	Sample			
Education		*		***				
	None	47	643	34	1053	13	8	18
	Primary	45	1718	29	4901	16	13	19
	Secondary+	41	388	26	1336	15	10	20
Occupation		NS		NS				
	Not working	45	1112	31	2002	14	10	18
	Professional & Tech	44	36	20	98	24	6	42
	Clerical & sales	39	320	29	1172	10	4	16
	Agriculture	46	1179	29	3128	17	14	20
	Household/domestic	59	22	25	73	34	11	57
	Services	42	73	30	817	12	0.2	24
	Others	71	7	31	3	40	6	74
Marital status		NS		***				
	Never married	45	416	28	1465	17	12	22
	Married	44	2009	29	4853	15	12	18
	Widowed	49	324	34	972	15	9	21
Partner education		**		**				
	None	48	342	35	572	13	6	20
	Primary	46	1455	29	3533	17	14	20
	Secondary+	39	517	28	1650	11	6	16
	No Partner	46	435	29	1535	17	12	22
Bed net use		NS		NS				
	No	45	2111	29	4094	16	13	19
	Yes	43	638	30	3196	13	9	17
Wealth status		NS		**				
	Poorest	47	398	32	1855	15	10	20
	Poorer	45	565	31	943	14	9	19
	Middle	45	567	29	1078	16	11	21
	Richer	43	717	28	1766	15	11	19
	Richest	45	493	27	1613	18	13	23
Total sample		**44**	**2749**	29	**7290**	**15**	**13**	**17**

***: p<0.01 **: p<0.05 *:p<0.1;NS: Not significant

By household wealth, the prevalence of anaemia among women in Malawi decreases with an increased household wealth. The difference between the poorer and wealthier was not significant in 2004; it is significantly lower in 2010. There are significant differences in the fall of anaemia between the two years. For instance the fall in wealth status is consistent across the wealth spectrum, but for occupation there are professions that the fall is higher (see Figure 7.1).

Figure 7.1 The prevalence of anaemia among women by household wealth status



The prevalence of anaemia among women in Malawi differs by the place of residence, the source of drinking water and by region (Table 7.3). The prevalence of anaemia is higher in rural areas, among those whose main source of drinking water are well/spring and among women from central region. Anaemia is much more prevalent in rural areas than in urban areas. The fall in the prevalence of anaemia between the two years is significantly different within both urban and rural areas. However, the fall in terms of percentage point change is slightly larger in rural areas (16) than in urban areas (13). With regard to the use of other sources as drinking water, the fall observed in anaemia level between the two years is not significantly different (percentage point change: 7; 95% C.I: -5 to 19) as depicted in Table 7.3.

The data suggest that although there has been a significant decrease in anaemia level within region in 2010 and between the two years, the fall is nearly two times higher in the northern region than it is in other regions.

Table 7.3 The prevalence of anaemia among women by year

Variable	Category	Anaemia DHS 2004		Anaemia DHS 2010		% point difference	95% C.I	
		%	Sample	%	Sample			
Place of residence		**		***				
	Rural	46	2391	30	6293	16	14	18
	Urban	39	358	26	997	13	7	19
Water source		NS		**				
	Piped/Tap	42	452	26	1603	16	11	21
	Wells/Spring	46	2219	30	5294	16	14	18
	Others	36	78	29	390	7	-5	19
Region		NS		**				
	Northern	47	440	26	1283	21	16	26
	Central	43	950	31	2562	12	8	16
	Southern	46	1359	30	3445	16	13	19
Total sample		**44**	**2749**	**29**	**7290**	**15**	**13**	**17**

***: p<0.01 **: p<0.05 *:p<0.1;NS: Not significant

7.3. Possible factors that might have contributed to a decrease in the prevalence of anaemia among women in Malawi in 2010

There has been significant and large fall in anaemia prevalence amongst women. Although this chapter focus on changes in anaemia prevalence among women, the anaemia level for children was checked and it is significantly lower in 2010. The prevalence of anaemia has decreased from 73% in 2004 to 64% in 2010, with a percentage point change of 9%. Two-sample test for proportion was carried out and the result suggest that the percentage point change of 9 (95% CI: 0.67 to 0.11) is statistically significant (t-test 7.41, p-value <0.001). In Malawi between 2004 and 2010 the health sector has had some reform policies which could partially explain significant fall in anaemia level amongst women and their children. These included Emergency Human Resources Programme (EHRP) implemented in 2005 aiming to increase and improve staffing levels for health services and malaria prevention programmes which distribute Insecticide Treated Nets (ITN) among vulnerable groups (Larson, Mathanga et al. 2012). The EHRP has had positive effect.

In this section, possible factors that might have contributed to a decrease in the prevalence of anaemia among women in Malawi are discussed. Anaemia is multifactorial. The factors that could influence the prevalence of anaemia include seasonal variation, micronutrient supplementation and political commitment in the prevention and control of other anaemia-related causes (e.g. Malaria, HIV and TB).

7.3.1 Seasonal variation in Malawi

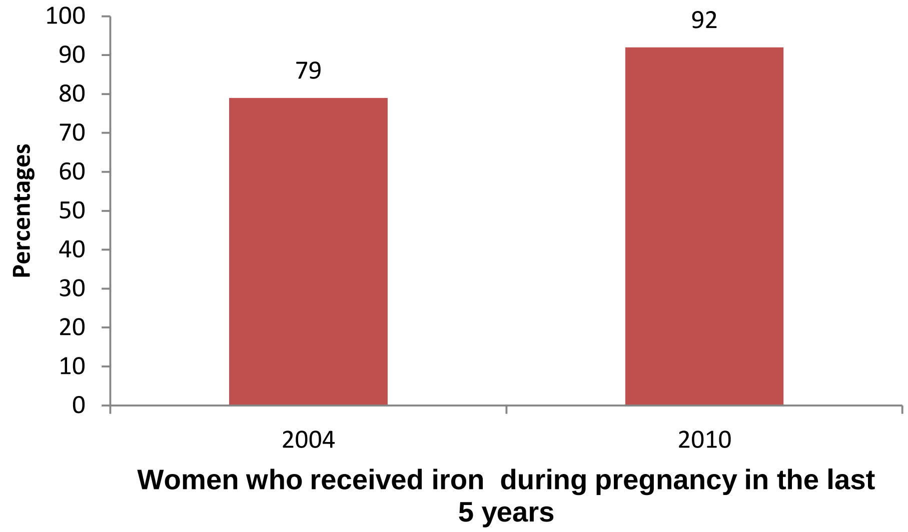
It is suggested that in regions with higher prevalence of malaria, anaemia is higher (Menendez, Fleming et al. 2000; Quintero, Siqueira et al. 2011). The climate in high malaria endemic areas is among many other factors that could increase or decrease the prevalence of both malaria and anaemia. The season could increase the prevalence of anaemia through a higher prevalence of malaria or through a decrease in food production. The weather in Malawi is stable and is divided into three seasons. The rainy season lasts from December to March, a cool and dry season from April until July and a hot and dry season from August until November (Squire 1979). The rainy season is hot and humid and is characterised by an increased level of malaria parasites (Sattler, Mtasiwa et al. 2005). The study by Slutsker and colleague used data from two hospitals in areas with different seasonal patterns of malaria, and although the prevalence rates of anaemia due to different seasonal patterns is not reported, the findings suggest that the impact of anaemia due to malaria is marked in areas with sustained pattern of malaria (Slutsker, Taylor et al. 1994). It could be argued possible that the prevalence of anaemia is higher during the rainy season because of high malaria transmission (Slutsker, Taylor et al. 1994). A study by Van den Broek et al. (2000) found that anaemia is highly prevalent during the wet season in Malawi (van den Broek, Rogerson et al. 2000). Seasonal variations in the prevalence of anaemia due to higher malaria transmission has also been documented and reported in Southern Nigeria and Malawi (Rogerson, van den Broek et al. 2000; van den Broek, Rogerson et al. 2000; Brabin, Premji et al. 2001; Oboro, Tabowei et al. 2002). During the hot and dry season, anopheles species are less likely to survive (Charlwood, Vij et al. 2000).

Data collection for anaemia and HIV testing for the 2004 Malawi Demographic and Health Surveys commenced on the 4th of October 2004 and was completed by 31st January 2005, which is during the rainy season (National Statistical Office and Macro 2005). However, data collection for the 2010 survey took place from June to November 2010, during a dry and hot season. Hence the fall in anaemia may partially be due to the season and malaria. In this study the prevalence of anaemia was computed for each month of interview. Clinical malaria was not measured in both surveys which made it difficult to test whether the prevalence of malaria also decreased. However, the prevalence of anaemia was tested by month of interview; no significant differences are found in the prevalence of anaemia among women by month of interviews for 2004 and 2010.

7.3.2 Micronutrient supplementation

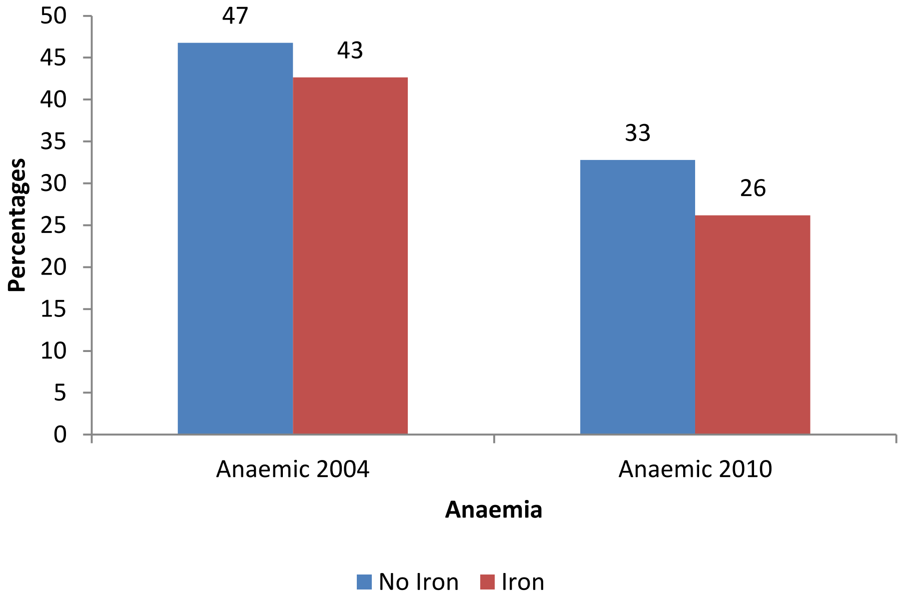
Adequate micronutrient intakes which women receive from micronutrient supplementation play an important role in women's and their children's health (Bartley, Underwood et al. 2005). To check whether iron supplement during the last pregnancy could be among factors contributing to the fall in anaemia amongst these women the samples were further reduced to only those women who reported on iron supplement during their last pregnancy. The data indicate a significant 11% increase (t-test p-value <0.001) in iron supplementation in women during their last pregnancy in 2010 (Figure 7.2).

Figure 7.2 Iron supplementation among women in their last pregnancy in Malawi by year



For both years under study, anaemia is less prevalent among women who received iron supplement during their last pregnancy than it is among those who did not see Figure 7.3. In 2010, anaemia is 33% prevalent among women who did not receive iron during their last pregnancy but it is 26% among those who did receive iron supplementation. This difference is statistically significant although very small (Pearson Chi-square statistic = 5.92; p-value 0.015). The difference in the prevalence of anaemia among women who received iron during their last pregnancy has decreased to 26% in 2010 from 43% in 2004, nearly 60% decreased in the prevalence of anaemia. The percentage point change of 17% between 2004 and 2010 is statistically significant (t-test statistic = 5.43; 95% C.I: 0.11 to 0.23; p-value <0.001).

Figure 7.3. The prevalence of anaemia among women who received iron during their last pregnancy by year



The time since last birth was also studied in order to check whether the prevalence of anaemia among women who took iron or not varies by the time since last birth. Time since last birth was grouped into 3 month intervals. The sample was limited to 60 months since last birth (about 5 years). For both 2004 and 2010 the data suggest that the prevalence of anaemia between those women who took iron and those who did not only differs for those women whose time since last birth is between 0 to 3 months (those who gave birth recently). However, anaemia level does not differ between women who took iron and those who did not for women whose time since last birth was over 4 months. This could be suggesting that iron supplement has no long term protective effects. As one would expect, those women who recently took iron are less likely to be anaemic (Figures 7.4 and 7.5).

Figure 7.4 The prevalence of anaemia in women by the time since last birth in Malawi in 2004

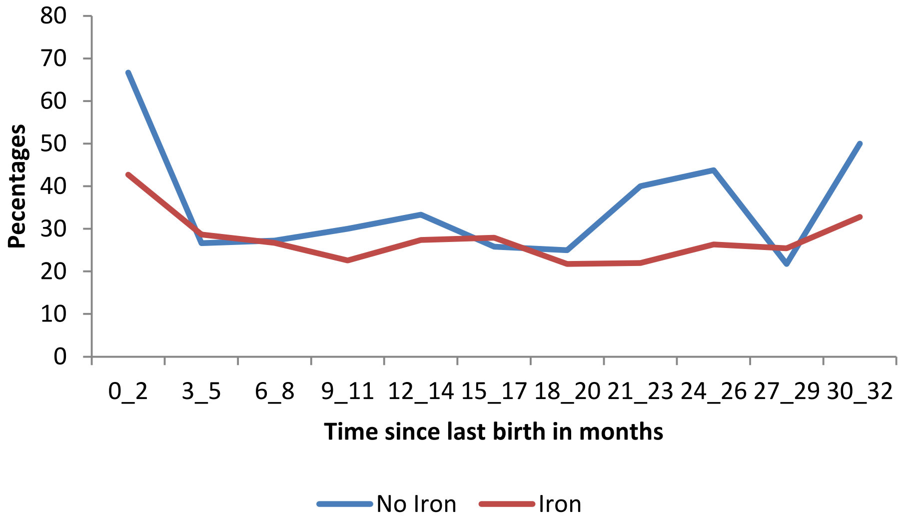
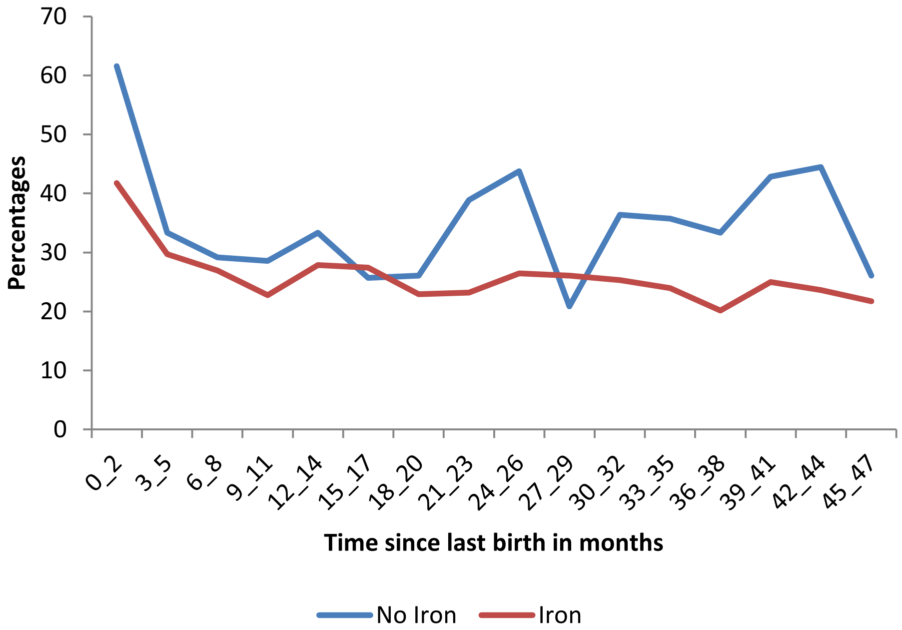
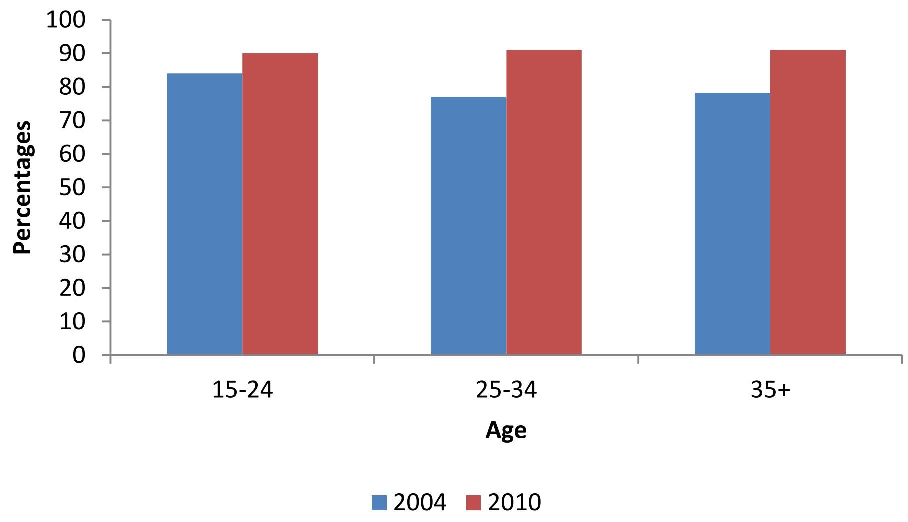


Figure 7.5 The prevalence of anaemia in women by the time since last birth in Malawi in 2010



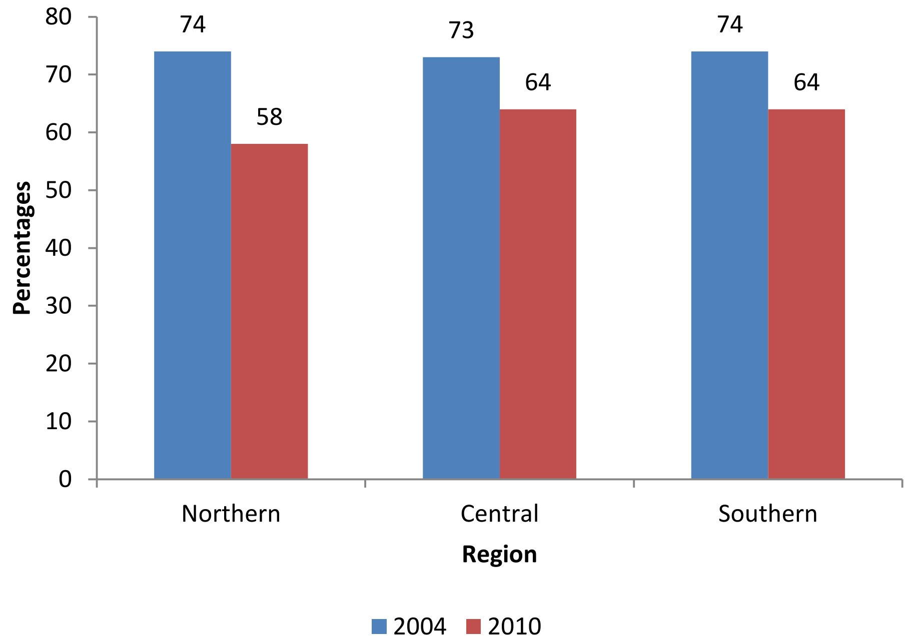
Further investigation of differences in the fall of anaemia level by age groups between 2004 and 2010 indicate that the big fall in anaemia level among older age group could probably be a result of an increase in iron supplements among women in 2010. The results suggest that in 2004 the proportion of those who received iron during their last pregnancy was higher among the youngest age group (84%) but slightly lower (77%) among those women aged 25-34, and 78% among women aged 35 and over. In 2010 however, it was the opposite, the percentage of women who received iron is slightly higher among those aged 25 years and over and slightly lower among the youngest age group (see Figure 7.6).

Figure 7.6 Percentages of women who received iron supplement by age and by year



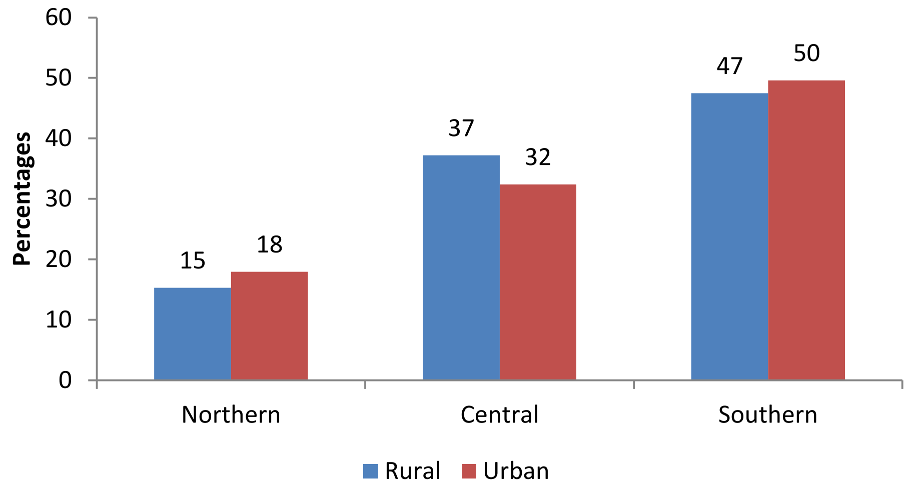
Although data from 2004 suggest no significant regional differences in the prevalence of anaemia among women and children in Malawi, the fall in the prevalence of anaemia significantly differs by region in 2010. The data from 2010 suggest that women from Southern and Central regions are more likely to be anaemic compared with women and children from the Northern region. It was also checked whether regional pattern of anaemia observed amongst women is the same for children as well. The prevalence of anaemia among children has also decreased. As for women, anaemia level for children is slightly lower in the Northern region in 2010. The prevalence of anaemia among children by region is depicted in Figure 7.7.

Figure 7.7 The prevalence of anaemia in children by region by year



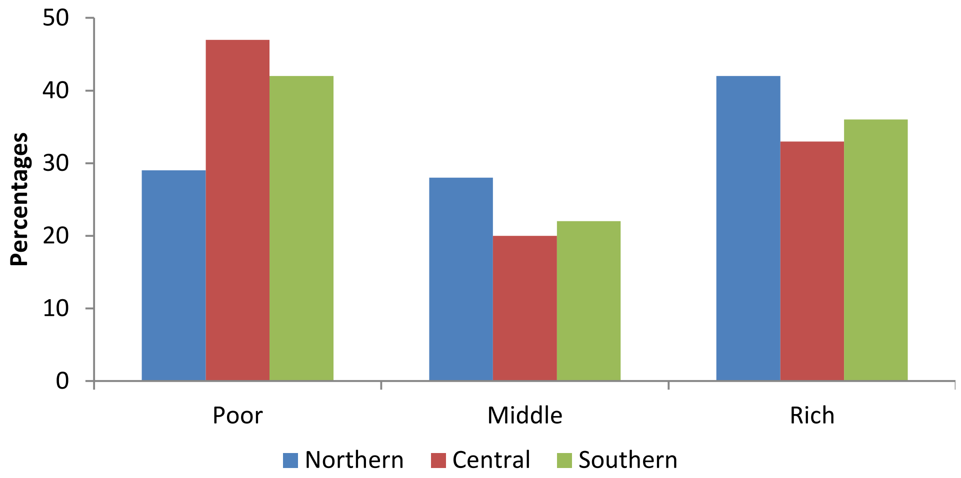
The greater reduction in the prevalence of anaemia among women is observed in the Northern region and this was significantly different from the central and Southern regions (percentage point change: 21; 95% C.I: 16 to 26). The Government's publication on poverty and vulnerability assessment, published in 2006, argued that there are many more poor people in rural than urban areas in Malawi and that both Southern and Northern regions share the highest rural poor population (Malawi Government and World Bank 2006). Compared with the Southern region, however, the Northern region is coping better in poverty reduction in terms of population living below the poverty and ultra-poverty lines. The number of people living below the poverty line (25%) is lower in the Northern region compared with the Southern region. Even in terms of the ultra-poverty line in rural areas one quarter of the population in the Northern region live below the ultra-poverty line compared with one third in the Southern region (Malawi Government and World Bank 2006). This was further checked by exploring the prevalence of anaemia by region by the place of residence, household wealth status and by women's BMI. With regards to the place of residence by region the data from 2010 indicate that the prevalence of anaemia is significantly lower in rural areas in the Northern region than it is in other two region (p<0.05); see Figure 7.8. However, no significant differences were found in anaemia level between the regions in the urban areas (p>0.05).

Figure 7.8 Anaemia level in women in Malawi by region and by place of residence in 2010



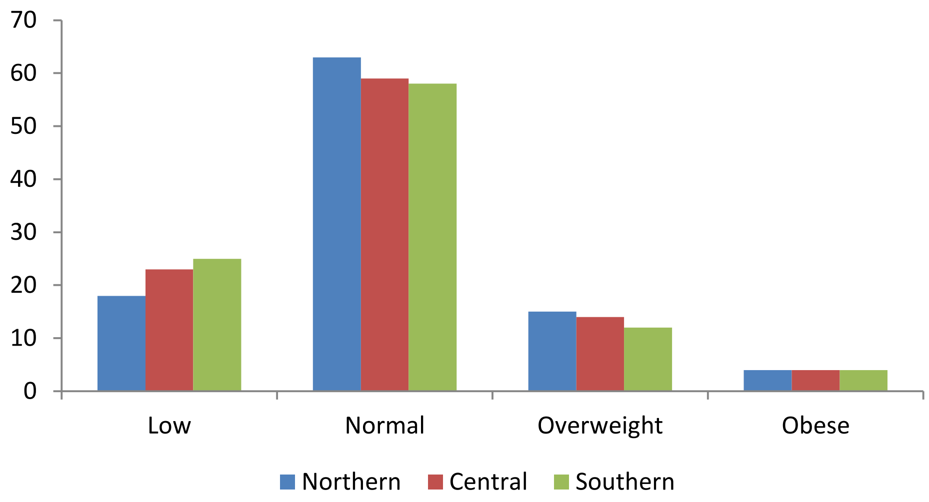
Malnutrition has long been recognised as a consequence of poverty. Household wealth status were investigated by region. The data suggest that Northern region shares the lowest percentages of poor and have higher number of rich (Figure 7.9)

Figure 7.9 Household wealth status by region in Malawi in 2010



Women's BMI were further explored by region to see whether those women in the Northern region have better nutritional status than their counterpart from other two regions. Women's BMI was checked by region and the data suggest that low BMI was higher among women from the South and lower among those from Northern region (Figure 7.10). 63% of women from the Northern region have a normal BMI against 58% from the Southern region and the difference is significant ($p<0.05$). The Southern region is faced with a number of environmental and socioeconomic problems. During the rainy season, almost every year the southern region faces floods from, amongst others, the Shire river. Flood leaves behind marshes from which mosquitoes responsible for malaria breed, contaminating water (Pirke, Schweiger et al. 1985). Flooding may sweep away crops and livestock in some part of the region creating food insecurity responsible for malnutrition and anaemia.

Figure 7.10 Women' BMI by region in Malawi in 2010



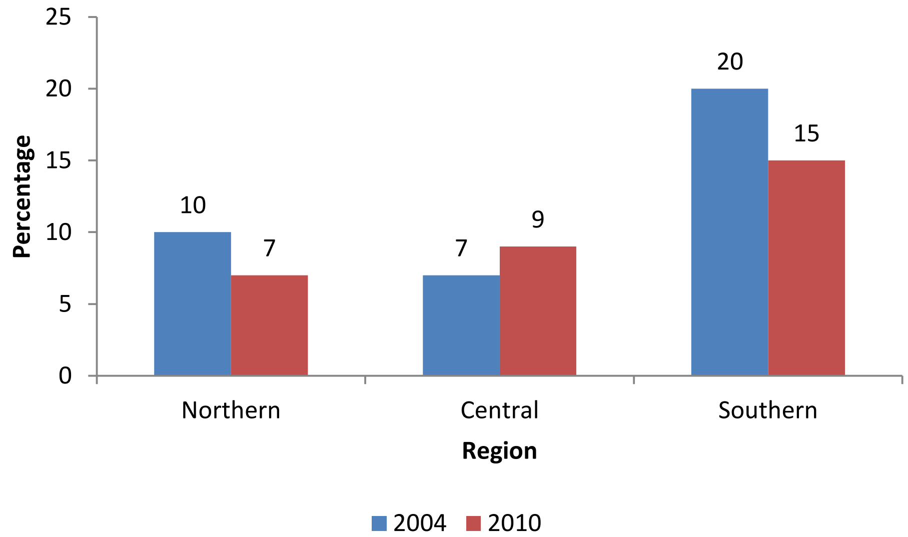
7.3.3 Political and regional commitment in reducing anaemia-related illnesses

Regional and local policy documents and programmes in Malawi between 2004 and 2010 emphasise the health of children and women, especially pregnant women in the fight against preventable illnesses such as malaria and diarrhoea, which are strongly related with anaemia (UNICEF 2006; Government 2007; Government 2008). Clinical malaria was not recorded; bed net is used instead as a proxy for malaria prevention. Bed net use has significantly increased to 44% in 2010 from 22% in 2004 (percentage point change, 95% C.I: 22%; 20-24). Although there are significant falls in anaemia prevalence for both women who used bed net and those who did not, one would expect the fall in anaemia prevalence to be bigger among those women who used a bed net than those who did not. However, the fall is slightly bigger among those women who did not use a bed net. Significant improvements have been made and success has been reported in the use of insecticide-treated nets and malaria (Holtz, Marum et al. 2002; Davis, Clark et al. 2006; Skarbinski, Mwandama et al. 2011). This chapter, however, found no significant differences between the use of a bed net and anaemia among women. This calls for more appropriate data that measure clinical malaria alongside social factors.

HIV is another cause of anaemia. Malawi's Government and collaborative donor have reformed the health sector and are investing in HIV/AIDS prevention and control. This health sector reform is an important measure which could explain the decrease in the prevalence of anaemia among women in Malawi in 2010 (EHRP 2010). The Emergency Human Resources Programme (EHRP) was designed in 2004 and implemented in 2005. Central to the EHRP commitment was the need to improve staffing levels for health services. Low level of health workers are overwhelmed by the demand for services as result of population growth and high levels of HIV/AIDS in 2004. Although the need to expand health services for the benefit of the country as a whole is still there, the EHRP evaluation final reports argue that with the implementation of the EHRP the Government have resulted in tangible increase in access to health services (Grobel 1972). The total number of professional health workers has increased by 53%, from 5,453 in 2004 to 8,386 in 2009. There is also an increase in utilisation in priority health services such as antenatal care visits and immunisation. The data suggest that the percentage of women with no antenatal visits during pregnancy has decreased to 1.12% in 2010 from 3.47% in 2004. It is during antenatal care where iron is supplied and health-related information is diffused, since more women are attending antenatal visits this could partially explain a decrease seen in the prevalence of anaemia in women in Malawi in 2010. Although not all pregnant women attend antenatal care, in most developing countries, and in Malawi in particular, public health measures focus on treating anaemia in children and pregnant women attending antenatal care.

In addition, other studies have documented the link between anaemia and HIV and have found strong positive association between anaemia and HIV (Bentley and Griffiths 2002; Bentley and Griffiths 2003). HIV/AIDS prevalence among women in Malawi has slightly decreased to 12% in 2010 from 15% in 2004. The UNAIDS estimation suggest that HIV incidence rates for both men and women of reproductive age in Malawi has also decreased to 0.95 (95% CI: 0.67-1.23) in 2009 from 1.35 (95% CI: 1.15-1.61) in 2001 (UNAIDS 2010). The decreases in HIV incidence rate could be among many other factors which partially explain the fall in the prevalence of anaemia among women in Malawi in 2010, since anaemia is 42% prevalent among HIV positive women. By region, HIV is much more prevalent among women from the Southern region than it is among those women from the Northern and Central regions (Figure 7.11). Regional differences observed in the prevalence of anaemia and HIV among women have a similar pattern. Both anaemia and HIV are higher in Southern region and lower in Northern region. This might suggest that the decrease in the prevalence of anaemia among women in Malawi in 2010 could partially be a result of a slight fall in the prevalence of HIV among this population group.

Figure 7.11 HIV prevalence among women by region and by year



7.4. Changes in the determinants of anaemia among women from 2004 to 2010

In this section, multilevel logistic regression is used to fit five models to account for the hierarchical nature of the data and investigate whether determinants of anaemia among women in Malawi in 2010 have changed from 2004.

The first model is as presented in Chapter 6 (Malawi country specific model) and only includes factors associated with anaemia in women in 2004. The second model uses Malawi Demographic and Health Survey from 2010 and also includes only factors associated with anaemia among women in 2010 (Table 7.4). The two other models include all factors associated with anaemia among women in 2004 and 2010 (Table 7.5). The last model combines data from the two periods and tests whether the time effect is significant. The results suggest that BMI and regions are unchanged factors associated with anaemia among women in Malawi in 2004 and 2010. There is a shift however, in other determinants of anaemia in women in Malawi in 2004 and 2010. As presented in Tables 7.4 and 7.5 the risk of anaemia in women in Malawi in 2004 differs significantly by age, partner’s level of education and breastfeeding. However, in 2010 anaemia in women differs by parity, educational level, marital status and pregnancy status.

Table 7.4. Determinants of anaemia among women in Malawi over time

Variable	Category	DHS 2004 OR	DHS 2004 95% CI		DHS 2010 OR	DHS 2010 95% CI	
Current age	15-24	1.00			NS		
	25-34	1.14	0.94	1.38			
	35+	**1.28**	1.03	1.58			
Parity	Zero	NS			1.00		
	One				**0.75**	0.65	0.86
	Two				**0.83**	0.72	0.97
	Three+				0.76	0.53	1.08
BMI	Low	1.00			1.00		
	Normal	1.01	0.84	1.21	0.93	0.82	1.05
	Overweight	**0.71**	0.53	0.94	**0.75**	0.63	0.90
	Obese	**0.52**	0.31	0.89	**0.64**	0.48	0.86
Partner's education	None	1.00			NS		
	Primary	0.98	0.77	1.24			
	Secondary +	**0.71**	0.53	0.95			
	No partner	0.89	0.64	1.24			
Education	None	NS			1.00		
	Primary				**0.84**	0.73	0.97
	Secondary+				**0.72**	0.60	0.87
Marital status							
	Never married	NS			1.00		
	Married				1.09	0.93	1.29
	Widowed				**1.40**	1.16	1.70
Pregnancy	No	NS			1.00		
	Yes				**1.71**	1.45	2.03
Breastfeeding	No	1.00			NS		
	Yes	**0.81**	0.69	0.96			
Region	Northern	1.00			1.00		
	Central	**0.78**	0.62	0.99	**1.20**	1.03	1.40
	Southern	0.89	0.71	1.11	1.13	0.98	1.31

The results suggest that the risk of anaemia among women in 2004 significantly varies by age group, and women aged 35 and older have an increased risk of anaemia compared with their counterparts who are younger. With reference to iron supplementation, the data indicate that the proportions of women who received iron supplement during their last pregnancy do not differ by age in 2010. The influence of BMI on women's risk of having anaemia has not changed in terms of their magnitude.

Women's probability of anaemia decreases with an increased BMI. The influence of anaemia on women from Central region has slightly changed in term of magnitude, the changes are borderline (95% C.I are close to containing1).

By educational level, the data also suggest that the proportions of women who received iron supplements increased with an increased level of education in 2010, while the proportion of women receiving iron supplements was slightly the same in 2004 (Figure 7.12). The results presented in Table 7.3 suggest similar findings. Women's risk of anaemia significantly differs by their level of education in 2010. It could be argued that iron supplement during the last pregnancy has played a significant role in decreasing anaemia among woman in Malawi in 2010. Variables such as iron, non-iron and non-pregnant were included in the models (not presented here) in order to check whether iron supplementation has protective effects for women's risk of having anaemia. The results suggest a protective effect of iron supplements (O.R; 95% C.I: 0.75; 0.59-0.95). Non pregnant women are associated with a 43% decreased risk of anaemia (O.R; 95% C.I: 0.57; 0.46-0.70).

Micronutrient supplementation among women in Malawi significantly differs by educational level and household wealth status in 2010 (Pearson Chi-Square = 9.5; p-value <0.042), but not in 2004 (Pearson Chi-Square statistic = 3.5; p-value <0.477). An increase in micronutrient supplementation (Vitamin A and iron supplementation) among women could be among many other factors which could explain lower prevalence of anaemia in women with at least a primary education and those women in the highest wealth quintiles in Malawi in 2010. Figures 7.12 and 7.13 indicate increased micronutrients (Vitamin A and iron) by educational level and household wealth by year. Iron supplementation among those women with at least a secondary education has increased to 96% in 2010 from 94% in 2004. Although a small percentage point difference of 2%, this difference is statistically significant (t-test statistic = 2.83; p-value 0.004).

Figure 7.12 Percentages of women who received Vitamin A and Iron supplement by education and by year

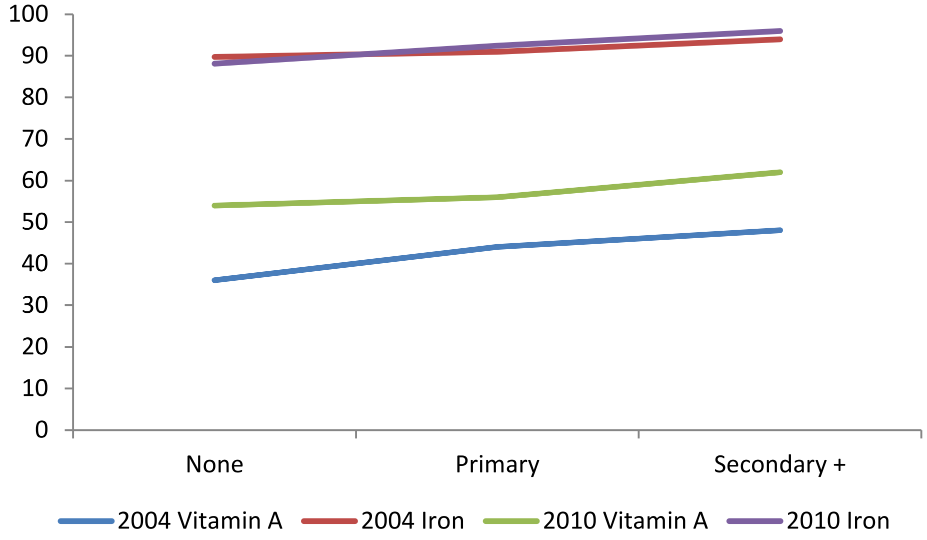
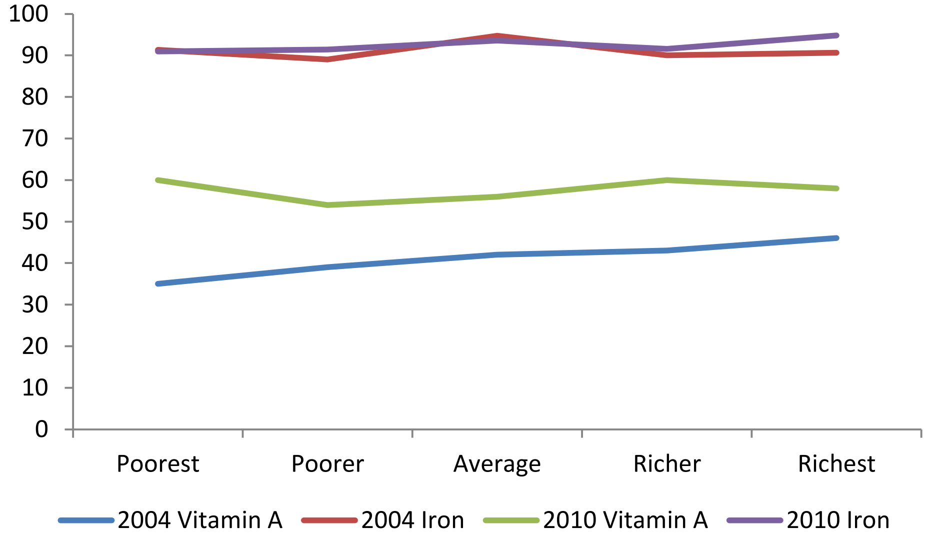


Figure 7.13 Percentages of women receiving Vitamin A and Iron supplement by wealth status and year



By marital status, those women who are widowed or separated are associated with higher risk of anaemia compared with married and never married women in 2010. HIV status is also found to be strongly related with marital status, and the data suggest that HIV is more prevalent among widowed or separated women in 2010. The increasing probability of anaemia associated with widowed or separated women in Malawi could be due to strong association between HIV and anaemia. The prevalence of anaemia is significantly higher among HIV positive women (42%) than it is among HIV negative (27%). All factors that were at least significant during one period were included to see whether the determinants of anaemia have changed over time. Results are presented in Table 7.5. After the effect of all factors (significant or not) were controlled for, it indicates that the determinants of anaemia in women during 2004 and 2010 are the same even in terms of the magnitude of their effects on women's risk of anaemia (Table 7.5). Time interaction was included in the model with all data combined. The results suggest that compared to the risk of anaemia in women in 2004 there is a 47% significant decreased risk of anaemia in 2010 (O.R; 95% C.I:0.53 (0.48-0.59).

Table 7.5. Determinants of anaemia among women in Malawi by year

		DHS 2004			DHS 2010		
Variable	Category	OR	95% CI		OR	95% CI	
Current age	15-24	1.00			1.00		
	25-34	1.12	0.92	1.37	0.90	0.78	1.03
	35+	**1.30**	1.02	1.65	1.03	0.87	1.21
Parity	Zero	1.00			1.00		
	One	1.03	0.82	1.29	**0.76**	0.66	0.89
	Two	0.94	0.71	1.26	0.85	0.70	1.03
	Three+	0.91	0.55	1.50	0.77	0.53	1.13
BMI	Low	1.00			1.00		
	Normal	0.97	0.81	1.17	0.93	0.82	1.05
	Overweight	**0.68**	0.51	0.91	**0.76**	0.63	0.91
	Obese	**0.50**	0.29	0.85	**0.65**	0.48	0.87
Partner's education	None	1.00			1.00		
	Primary	0.94	0.73	1.20	0.83	0.69	1.01
	Secondary +	**0.70**	0.51	0.96	0.86	0.69	1.07
	No partner	1.60	0.60	4.28	0.93	0.55	1.59
Education	None	1.00			1.00		
	Primary	0.98	0.80	1.20	0.87	0.75	1.02
	Secondary+	0.96	0.70	1.31	**0.76**	0.62	0.93
Marital status							
	Never married	1.00			1.00		
	Married	1.73	0.64	4.68	1.20	0.70	2.06
	Widowed	2.02	0.74	5.49	1.54	0.90	2.65
Pregnancy	No	1.00			1.00		
	Yes	1.23	0.95	1.60	**1.76**	1.46	2.11
Breastfeeding	No	1.00			1.00		
	Yes	0.88	0.70	1.12	1.03	0.88	1.20
Region	Northern	1.00			1.00		
	Central	**0.78**	0.62	0.99	**1.20**	1.03	1.39
	Southern	0.88	0.71	1.11	1.13	0.98	1.31
Total Sample size		***2749***			***7290***		

7.5 Discussion and Conclusion

The aims of this chapter were to explore and discuss changes in the prevalence of anaemia in women in Malawi between 2004 and 2010, and to identify and discuss possible factors which might have brought about the changes. The results show that the prevalence of anaemia among women in Malawi in 2010 has significantly decreased. Seasonal variation, micronutrient supplementation and health policies reforms could be amongst many other factors which might explain the changes in the prevalence of anaemia between the two periods.

With regard to seasonal variation, data for the two periods under study were collected in two different seasons. The 2004 data were collected during a wet/rainy season while data for 2010 survey were collected during a dry/hot season. Seasonal variation can influence individual’s risk of anaemia in two ways. First, the season can increase the risk of anaemia through other seasonal illness such as malaria which is much more prevalent during the wet/rainy season. Malaria has been found to be strongly related with anaemia and studies have argued that in setting where malaria is endemic anaemia is much more prevalent (Greenberg et al. 1988; Anstey, Granger et al. 1999; Reyburn et al. 2005). Clinical malaria was not reported in these data which makes it hard to prove the direct link between anaemia and malaria. Bed net use as a proxy for malaria prevention has significantly increased in Malawi between the two periods. However, no direct significant association was found between the use of bed net and anaemia in women in this chapter.

Secondly, seasonal variation, especial the dry season has significant impact on food production and distribution in rural areas which can directly influence nutrition. In rural areas of developing countries, climatic seasonality is associated with nutritional problems due to food availability and storage (Ndekha, Kulmala et al. 2000). No dietary intakes were measured for women in these two surveys. Although there was no significant differences in the prevalence of anaemia by months of interviews, the results from this study are consistent with studies which argue that the prevalence of anaemia is higher during a wet/rainy season (in 2004) but lower during dry/hot season in 2010 (Slutsker, Taylor et al. 1994; Verhoeff, Brabin et al. 1999; Rogerson, van den Broek et al. 2000).

A slight increase in micronutrient supplementation could be among other contributing factors to the decreasing prevalence of anaemia among women in Malawi in 2010. The results suggest an increase in proportion of women who received antenatal care and iron supplements in 2010 than it was in 2004. Regardless of women’s socioeconomic characteristics, those women who received iron supplements are associated with a lower prevalence of anaemia compared with those who did not. Supplementation with micronutrients was found to be effective not only for women but also for their children, and the earlier it is taken, the better (Seibel 1999; Cetin, Berti et al. 2010; Alaigh 2011; Kawai, Spiegelman et al. 2011). The majority of women of reproductive age in developing countries consume diets of low iron bioavailability and therefore are likely to start their next pregnancy with no iron stores and low haemoglobin concentration. Yet, there are limited anaemia preventive measures for non-pregnant women. Anaemia interventions are focused on pregnant women who receive antenatal care. In Malawi for example iron and Vitamin A supplements are given during pregnancy only.

Beneficial effects of education on women’s probability of having anaemia as suggested in this chapter are as argued in epidemiological studies (Reed, Habicht et al. 1996; Glanz and Rimer 2008). Education can influence eating habits and the choice of food (Stein and Fairburn 1996). Educated women can easily welcome advice or information about how to deal with changes in eating pattern.

Changes in the determinants of anaemia among women over time have highlighted the identification of population groups of individuals exposed to anaemia. Nutritional problems associated with climatic seasonality in rural areas of developing countries could be alleviated with selective food storage and the development of agriculture. More studies with longitudinal data including dietary information and clinical malaria are needed to serve as a decision support tool to contribute toward prevention and control of anaemia.

CHAPTER 8
Discussion and conclusion

8.1 Introduction

Anaemia is a major public health problem for DRC, Uganda and Malawi. The question in relation to the scourge of anaemia is not whether these nations can control or prevent anaemia but how much will-power (this include political will-power) do these countries have as nations to reduce the prevalence of this health disorder, yet of a major public health concern. Anaemia can easily be prevented through simple and inexpensive methods. What is required is commitment and relevant nutritional education including relevant awareness campaigns. The people of DRC, Uganda and Malawi should be made to understand the stakes involved in fighting the disorder. This is the only way to guarantee that the limited necessary resources will be allocated in sufficient quantities and on time. All stakeholders, researchers, politicians, health professional, the financial sector and the communities at large, must take the necessary bold steps forward.

The thesis has explored the prevalence and socioeconomic risk factors of anaemia among children and women in DRC, Uganda and Malawi. This chapter will discuss and summarise the major findings obtained from the foregoing chapters with reference to research questions presented in chapter 1, and draws some specific conclusions regarding the prevalence and social risk factors of anaemia. The main objective of this study was to explore the prevalence of anaemia among children and women and to provide an understanding of socioeconomic risk factors related to anaemia.

In spite of the shortfalls that come with the cross-sectional data, this study has shown that there is still high prevalence of anaemia in both children and women. The study has also shown that anaemia is endogenous to child nutritional status (weight-for-age z-scores) and that most of the observed and unobserved factors which might expose children to the risk of anaemia could also decrease children's weight-for-age z-scores. The study has further shown that there are significant associations between anaemia and socioeconomic and demographic conditions mainly in families and within individuals. With regards to the prevalence of anaemia, the study has shown that there are variations between communities within the three countries.

This study makes a contribution in exploring socioeconomic and demographic factors related to anaemia and its application of endogenous switching regression model to explore the link between anaemia and children nutritional status. Endogenous switching regression model suggests that anaemia and child weight-for-age z-scores are strongly correlated and that the same observed and unobserved factors could not only expose children to anaemia but also to low weight-for-age z-scores (below -2 standard deviations). The results from multilevel analysis (multilevel ordinal and logistic regression models) give estimates of fixed as well as random factors which are more robust than what could be obtained from standard individual-level analyses because they take into account communities and households factors in the process avoiding underestimation of standard errors.

Age, sex, maternal education, maternal anaemic status, the place of residence and the region are commonest risk factors associated with anaemia among children in the three countries. There are no significant differences in the risk of anaemia between the three countries.

8.2 Methods

Chapter 3 aimed to describe data used in this thesis, standard models used in Chapters 4, 6 and 7 from model selection to the interpretation of results and the country justification. Each model was chosen after testing factors one after the other and testing for interactions. The distributions of the residuals were checked before to choose a suitable model for the data and after to check the distributional assumptions. Multilevel ordinal regression model were used to account for both the ordered nature of anaemia levels in children and the complex design of the data. The effect of anaemia could be mild, moderate or severe. For children anaemia levels were used on the ordinal scale because it is argued that even mild anaemia can impair children's emotional and cognitive performance (Walter 1994; Walker, Wachs et al. 2007). Based on the distribution of the residuals of women's haemoglobin levels and complex sampling design, multilevel logistic regression models were used for anaemia among women. Ignoring the hierarchical structure due to community levels in the data would have resulted in individual-level analysis for the prevalence data. In other words, the variation between communities as suggested in this study could have been measured by incorporating separate terms for each community. This would have been inefficient because the procedure would have involved estimating many times more coefficients than the multilevel procedure (Rabshal et al., 2004). It could have also been inadequate because it would not have treated communities as a random sample and hence would not have provided useful quantification of the variation among communities. By focusing attention on the levels of hierarchy, this thesis has been able to explain where variations and effects in general are occurring. For example, the results from Chapter 4 and 6 have shown that variation in anaemia in children and women prevalence occurs at the community level.

Endogenous switching regression models were used to model jointly anaemia and children's nutritional status (weight-for-age z-scores). In other words, some of the observed and unobserved factors that might expose children to the risk of anaemia could also decreases children weight-for-age z-scores. Including anaemia in the model that estimates mean weight-for-age z-scores (or vice versa) could bias the estimates of individual's factors in the model. This study has shown that the effect of some factors is underestimated where it is overestimated for other factors when endogeneity is ignored. Chapter 5 has come to the conclusion that studies pertaining for children nutritional status in settings where anaemia is highly prevalent should not treat anaemia as an exogenous factor. Thus ignoring community random effects (Chapters 4 and 6) and endogeneity (Chapter 5) in this study would have possibly led us to certify certain predictors significant when in fact that could have been ascribed to chance. Wrong conclusions could have been made.

8.3 Anaemia prevalence among children

Chapters 4 and 6 give thorough examination of the prevalence of anaemia and socioeconomic and demographic factors associated with anaemia among children and women in DRC, Uganda and Malawi. The chapters proffer some answers to questions about the coexistence and the role of community or household random effects.

In spite of shortfalls of the cross-sectional study (e.g. recall biases which is relevant for self-reported variables such as age and the size at birth), anaemia prevalence in children still very high (more than 70% in all three countries) when compared to the average in developing countries which is about 50% (Simondon, Benefice et al. 1993). With reference to the WHO criteria for ranking the prevalence of anaemia in women and children as a public health problem, the results from this thesis suggest that in DRC, Uganda and Malawi anaemia is a severe public health problem, the prevalence of anaemia for both women and children is over 40% (WHO, 2001).

There are shared or overlapping risk factors of anaemia for both women and children, which may be influenced by various factors and conditions in the three countries. Common risk factors include region of residence. Specific factors that interfere with children’s risk of anaemia are age, sex, maternal level of education, whether the mother is anaemic, and the source of drinking water, fever and household wealth status.

Younger children (<2 years old) are more likely to be anaemic compared to those aged between 2 and 5 years old. The effect of age on anaemia and other nutritional status is of particular interest and has been discussed. The increased likelihood of anaemia and other nutritional status in young children could be due to underdeveloped immune systems in infants, malnutrition and lack of child health knowledge (Jamison and Mosley 1991; Clegg and Weatherall 1999).

Males are more likely to be anaemic than females. This difference could be due to biological factors which this study cannot be able to explain. It is argued that the estimated energy requirements for infants of the same age differ by sex. Males need more energy (kcal/day) than do females (Multitopic 1989). Children from households that use piped water as the main source of drinking water are less likely to be anaemic compared with those who use other sources. Improved water quality is argued to have dramatically improved the public health by managing waterborne exposure and related diseases (Kolsky 1993; Montgomery and Elimelech 2007). In DRC, Uganda and Malawi, for some communities, access to improved drinking water is, or may soon be, limited by the presence of environmental pollutants in local water sources, flooding events that overwhelm local treatment capacity and failure in water-related infrastructure.

Children who have fever, a proxy for malaria, are more likely to have anaemia. A strong correlation between anaemia and malaria has been documented elsewhere (Woodruff, Ansdell et al. 1979; Anong, Akenji et al. 2005). Malaria exposes children to anaemia (Abdalla, Weatherall et al. 1980). Significant unexplained variations in children and women's risk of anaemia between communities within the three countries as found in Chapters 4 and 6 emphasise the influence of unobserved factors such as cultural norm (e.g. food taboos), political conflicts (e.g. war), behavioural (e.g. eating habits) and environmental factors. These observations have important implications towards integrated disease management especially in children and women.

8.4 Anaemia and child nutritional status

Chapter 5 analyses the link between anaemia and child nutritional status (weight-for-age z-scores). Weight-for-age z-score is often referred to as a proxy of malnutrition.

There is strong correlation between anaemia and weight-for-age z-scores which need to be accounted for. Anaemia may influence low weight-for-age z-scores and vice versa. Anaemia is endogenous to weight-for-age; most of the observed and unobserved factors which might affect child weight-for-age z-scores could also expose children to anaemia. Anaemia and weight-for-age z-scores can also occur concomitantly. Compared to non-anaemic children, mean of weight-for-age z-scores are lower for anaemic children regardless of their socioeconomic characteristics. Children of anaemic mothers have relatively lower mean weight-for-age z-scores.

Younger children (<2 years old), anaemic or not, are associated with low mean weight-for-age z-scores. Large demand for iron during growth and insufficient intake of iron in children's usual diet at this age are among known reasons for greater vulnerability of children under the age of two (Engstrom, Castro et al. 2008). The average weight-for-age z-scores for males is lower than it is for females. Similar results have been reported elsewhere, suggesting that male not only have low mean weight-for-age z-scores but also low height-for-age (Waters, Saadah et al. 2004; Lodhi, Mahmood ur et al. 2010). Sex differences in children's nutritional status might be due to biological conditions.

Children's mean weight-for-age increases with an increased maternal level of education. Maternal education can improve child health through the use of treatment and preventive services where health care system is available (Hadden and London 1996). Maternal education can lower death rates and improve child health and nutrition although some studies argue that this association is weaker when other factors (such as drinking water, the place of residence) are controlled for (Caldwell 1979; Barrera 1990; Schultz 2002).

Children's mean weight-for-age z-scores increase with an increased household wealth status. Wealthier is indeed healthier. It has been argued that at the household level, household wealth improves child health in the same way that economic development can improve child health nationally (Boyle, Racine et al. 2006). Household wealth provides an opportunity to improve the material circumstances of the family and household ability to purchase goods and services that can enhance health (Pritchett and Summers 1996; Biggs, King et al. 2010). There is a positive association between poor health and poverty. In societies where the poor suffer poor health the very poor suffer it appallingly (Feachem 2000). If endogeneity between anaemia and weight-for-age z-scores is ignored the results from Ordinal Least square regression can be misleading.

Child undernutrition is pervasive and a damaging condition in less developed and middle income countries (Black, Allen et al. 2008). In less developed countries both anaemia and undernutrition in children are major public health concern. For Sub-Saharan Africa, the average prevalence of undernutrition (low weight-for-age z-scores, z-score value <-2.0) is estimated at 25%. This prevalence varies from one country to another within the region. In DRC, the prevalence of undernutrition is similar (24%) to the regional average, while the prevalence of undernutrition is slightly lower in Uganda (15%) and Malawi (17%). Micronutrient deficiency is prevalent in children in DRC, Uganda and Malawi (Young, Berti et al. 2002).

It could have been interesting to see whether there are significant variations within these countries by including random effects. However, the use of random effects in simultaneous regression models is still underdeveloped. Future studies, therefore, will focus on including random effects with simultaneous switching regression models. Strong significant relationship between anaemia and weight-for-age z-scores highlights common risk factors and hence the need for common approaches to fighting anaemia and child malnutrition. The chapter has shown that anaemia and malnutrition are not a matter of food factors only, but also a matter of non-food factors (such as socioeconomic and demographic and environmental conditions) associated with low food availability. In countries such as DRC, Uganda and Malawi, with very low food availability non-food factors, such as maternal education and household wealth status, need priorities in policies to reduce malnutrition. More research is needed to unravel more risk factors associated with both anaemia and child nutritional status.

8.5 The prevalence of anaemia among women

The results from Chapter 4 & 5 have highlighted the impact of maternal health on children's risk of having anaemia and nutritional status. The results have shown that children of anaemic mothers are associated not only with a higher risk of having anaemia but also with lower mean weight-for-age z-scores. Maternal nutritional status is an important determinant of child health (Rahman, Roy et al. 1993; Koblinsky 1995; Black, Allen et al. 2008). Chapter 6 therefore has analysed factors that influence women's risk of anaemia in order to understand the epidemiology of anaemia among both children and women. The chapter has shown that nearly half of women are anaemic in DRC, Uganda and Malawi. Besides many other unknown factors which could influence women's risk of anaemia age, parity, BMI, pregnancy, marital status, place of residence and region are factors associated with anaemia among women in DRC, Uganda and Malawi.

Anaemia among women increases with an increased age. The older a women is, the greater their exposure to anaemia. High prevalence of anaemia observed among women aged 35 years and above could be due to many factors including premenopausal conditions. Clinical studies argued that with an increased age, before menopause, most women might experience abnormal uterine bleeding (Marret, Fauconnier et al. 2010).

Women who are underweight have greater risk of anaemia. Another significant risk factor of anaemia among women is pregnancy. Pregnant women constitute the main adult risk group for anaemia. Immunity is normally low in pregnant women and their exposure to infection/diseases (such as malaria and anaemia) is greater compared with women who are not pregnant living in the same area (Luxemburger, Ricci et al. 1997). Higher risk of anaemia among pregnant women varies by whether they are married or not. Pregnant women who are widowed/divorced are more likely to have anaemia compared with those who are married. A country variable suggests that the differences observed in women’s risk of anaemia between the three countries are not statistically significant. However, there are significant regional differences in women’s risk of anaemia within DRC, Uganda and Malawi. These differences could be due the environmental, climatic and economic conditions.

For both women and children there is more significant variation in anaemia prevalence between communities. Excess variability for anaemia may be due to spatial variability at community levels which could not be captured in the multilevel models used in Chapters 4 and 6. While multilevel models avoid important biases in estimates and standard errors for risk factors by relying on space fragmented areas such as communities, spatial techniques, the use of place indicators that consider the space near the individual’s place of residence thereby overcoming the fragmentation of the space into areas when formulating the correlation structure (Chaix, Merlo et al. 2005). But in the absence of continuous space information multilevel techniques are the alternative. Significant variation for anaemia observed at community level in DRC, Uganda and Malawi may be due to some unobservable factors that have not been captured by this thesis. For example, political, environmental and climatic factors such as conflicts common in these countries, may lead to food shortage resulting in malnutrition or overcrowding which are important factors of anaemia and other diseases (Caulfield, de Onis et al. 2004). Direct longitudinal community studies may be appropriate to capture some practices/situations missed by the cross-sectional data. HIV may be a potential risk factor which may explain community structured residuals variation in anaemia in women and children. It is argued that, in countries with high HIV prevalence such as DRC, Uganda and Malawi the relationship between anaemia and fever might be due to the fact that symptoms of HIV include fever and anaemia.

8.6 Changes in anaemia prevalence among women in Malawi from 2004 to 2010

The research question that is discussed in this section is ‘What is the trend in the prevalence of anaemia among women from Malawi, and what factors can be identified as contributing to changes in anaemia level amongst women in Malawi between 2004 and 2010?’. Anaemia prevalence among women in Malawi has significantly decreased. Amongst factors that could bring about the changes are seasonal variations, an increased in micronutrient supplementation (vitamin A and iron), a slight fall in HIV prevalence and socioeconomic factors such as education and wealth status.

Higher prevalence of anaemia observed in 2004 (data collected during rainy season) could be a result of many factors including climatic conditions and a direct link between anaemia and malaria. During the rainy season, some parts of the lands in the country, especially in the Southern region, remain under water due to flooding. Flooding lead to inundation of rural or urban riparian areas which directly impact on land use and management (O'Connell, Ewen et al. 2007). The drive for self-sufficiency in food production is still predominant in rural areas of developing countries and flooding can contribute to anaemia through shortage of food because flood swipes away crops and can displace livestocks (Bi and Parton 2008). Flooding areas also leave behind marshes which serve as a basin for mosquitoes to breed, the main factor that causes malaria which is associated with high risk of anaemia (Klinkenberg, McCall et al. 2006).

Micronutrient supplement (Vitamin A and iron) is argued to be an accepted and efficient treatment for nonhereditary anaemia, and the results from this study are in line with other research suggesting that iron supplement are associated with significantly reduced prevalence of anaemia (Cogswell, Kettel-Khan et al. 2003).

HIV and anaemia are strongly related. Anaemia is the most common complication seen in people with human immunodeficiency (HIV) and acquired immunodeficiency syndrome (AIDS) (Clegg and Weatherall 1999). It is suggested that up to 95% of HIV AIDS patient may have anaemia (Nichter 1984). Although it is difficult to measure the prevalence of anaemia in this population which is attributable to HIV, it could be speculated that a small fall in HIV incidence and prevalence in Malawi in 2010 could be among many other contributing factors to the decrease in anaemia prevalence. Protective effects of education on health as suggested in Chapter 7 could be explained throughout behavioural change that influences good nutrition. Protective effect of wealth on anaemia highlight the fact that wealthier can be healthier. More analysis is needed using longitudinal data including dietary intakes in order to describes these changes and understand factors contributing to the changes.

8.7 Anaemia prevention

Anaemia is a worldwide public health concern due to its effects on children's development and women, and due to the magnitude of current prevalence levels. Available estimates suggest that in developed and less developed countries, 12% and 51% respectively of children less than five years of age are anaemic, respectively (Engstrom, Castro et al. 2008).

Countries such as the United State of America have reduced anaemia among children to under 1%, whereas in DRC, Uganda and Malawi the prevalence of anaemia among children is as high as 74%, 73% and 71% respectively and still high compared with the overall of 51% for less developed countries (Engstrom, Castro et al. 2008). The non-specific signs and symptoms associated with anaemia might be among factors that lead to under-recognition of anaemia in developing countries (Kahigwa, Schellenberg et al. 2002). Anaemia can be a result of a combination of many factors (including poor diet, infections, and biological abnormalities and socioeconomic factors) but can easily be treated. Iron deficiency anaemia accounts for almost 50% of the world anaemic population. The international organisation has recommended the following three strategies to prevent and control for anaemia, especially iron deficiency anaemia (Morris and

Zidenberg-Cherr 1999). Nutritional education, food fortification and iron supplementation. In this study it is suggested that the use of any of the recommended strategies should be tailored to local conditions because not only of differences in dietary intake across the globe but also because of regional differences suggested within DRC, Uganda and Malawi.

Promoting nutritional education is important and can improve healthy behaviours and lifestyle which can prevent population from anaemia and other microdeficiencies (Hausman and Ruzek 1995; WHO 1998; Briggs, Safaii et al. 2003). Educating women could facilitate communication and behavioural changes, especially dietary intakes, individual perception of the society, food taboos. Nutritional education should take into account community and regional differences observed within countries.

Food fortification with iron and other micronutrients is another strategy to prevent anaemia, especially iron deficiency anaemia in populations. It has shown to be effective and efficient in a number of countries (Huma, Salim-Ur-Rehman et al. 2007). Food fortification should include dietary modification that can increase iron and other micronutrients absorption (WHO 2011b; WHO 2011c). It is argued that food fortification is one of the most effective approaches to prevent anaemia in population (Lokeshwar, Mehta et al. 2011). This is for a number of reasons: (1) if well planned it can reach most or all population groups, (2) the cost can be lower than oral supplementation of iron. The problem with food fortification is to identify a suitable food consumed by all population groups to be fortified and find the form of iron which is not only affordable but will not alter the taste of the food. Iron supplementation is another approach used when rapid correction of anaemia (e.g. severe anaemia) is needed. However, this approach has side effects that can be minimised with careful administration of iron (Lokeshwar, Mehta et al. 2011).

With reference to the conceptual framework (Figure 2.2), this study has shown that socioeconomic and demographic characteristics of children and women in DRC, Uganda and Malawi are among many other factors that can exacerbate children's or women's risk of anaemia and therefore need to be accounted for when preventing children and women from anaemia. There is a need to increase micronutrient supplements (e.g. iron and Vitamin A) to vulnerable population groups such as children below the age of 5 years old, children of anaemic mothers, all women of reproductive age (especially pregnant women) and children and women from the lowest wealth quintiles. Feeding practises need to be improved. Human milk contains sufficient energy and protein for infant during the first six months of life (Picciano 2001; Wijndaele, Lakshman et al. 2009). Breastfeeding during the first six months of life provides the ideal food for the healthy growth and development of infants. It is not only beneficial for infant but also constitutes an integral part of the reproductive process with important implication for the health of the mother. For example, breastfeeding is argued to protect the mother mental health (Kendall-Tackett 2007). The WHO recommends that infant should be exclusively breastfed for the first six months of life in order to achieve optimal growth, development and good health (WHO 2001). After the six first months of life, it is recommended that "infants should receive nutritionally adequate and safe complementary foods to meet their nutritional requirements while breastfeeding continues for up to two years of age or beyond" (Kent 2006).

Anaemia and other nutritional deficiencies can be both a cause and consequences of poverty. Targeting effort should include reducing poverty, improving infant and young child feeding practices, promoting community based nutrition interventions, and encouraging people to diversify and modify their diets. Other non-food based strategies include prevention and control of infections, environmental health measures. Infections, such as HIV/AIDS, and parasitic diseases, such as malaria, diarrhoea and hookworm, interfere with anaemia. Reduction of anaemia should receive top priority through proper planning by better utilisation of available local resources and health infrastructure.

As argued by the WHO, in less developed countries and as in DRC, Uganda and Malawi, policy and program decision makers have incomplete guidance on how to address young child iron deficiency anaemia (WHO 2011b). The focus of recent health policies in the three countries is on women and children attending antenatal care. In DRC, Uganda and Malawi, the lack of institutional and operational capacity to scale up good quality health services could challenge the integration and implementation of anaemia control and prevention measures. The WHO and various voluntary agencies are trying to disseminate information about anaemia, rarely mentioned as being important to be included in health care priorities for the future (Weatherall and Clegg 2001; WHO 2011c). With reference to current health policies and programmes within Malawi and Uganda, the recommended measures such as nutritional education, food fortification, Vitamin A and iron supplementation, the prevention and control of other infectious diseases, anaemia control and prevention could be effective (Weatherall and Clegg 2001; Balarajan, Ramakrishnan et al. 2011; De-Regil, Jefferds et al. 2011). Although it will take considerable time in DRC, Uganda and Malawi to the control and management of anaemia, it is not an impossible task.

8.8 Limitations

Finally this thesis is not without its limitations. The data used in this thesis are retrospective cross-sectional data reporting by individuals in each household. This may create biases due to incomplete responses and the response relies on memory. Demographic health surveys require respondents to recall information on children up to 5 years which may bring recall bias. Recall bias is argued to be related to level of mother's education, with more educated mothers most likely to remember information such as the age of the child, weight at birth. Therefore, controlling for mothers' education in the analysis may have captured a large part of the self-selective nature of reporting (Kazembe, Muula et al. 2009).

In this thesis, I have analysed socioeconomic and demographic risk factors associated with anaemia among children and women. However, the thesis could not go deeper to explore risk factors associated with behavioural practices often driven by cultures. Earlier studies have shown that eating practices are strongly associated with anaemia (Kawai, Saathoff et al. 2009). More analysis outside this thesis is, therefore, required to examine such behaviours to give more solid picture of anaemia in DRC, Uganda and Malawi.

Another limitation in this thesis is the weighting due to complex survey data design. In Malawi, for example, to avoid under or over-representation of some districts, the allocation of districts did not use proportional allocation. Some stratums (districts) from the Northern region and urban areas were oversampled to account for smaller population size. Therefore weighting is required to obtain representative estimates of the results. However, applying weights when using multilevel modelling techniques is difficult provided the weights are given for different levels in the models. In situations where weights are known at different levels sample weighting for continuous response models will be unbiased, but the estimates still biased for discrete response models (Chambers, Sugden et al. 1998; Pfeffermann, Skinner et al. 1998; Rabe-Hesketh and Skrondal 2006). In this thesis weights were only applied for initial model exploration, but not with multilevel ordinal and logistic models.

Despite the high response rate for anaemia testing for both children and women in all three countries, the analyses in this thesis were conducted under the assumption that the very few data missing (less than 15% for both children and women in all three countries) are missing at random (MAR). This assumption could possibly be challenged with the fact that the chance of being tested could indeed be related to the level of anaemia. For example children or women with severe anaemia might not be present at home on the night of the survey, but at the hospital for blood transfusion, and thus the data would be missing not at random (MNAR). However, this cannot be verified, and there is a possibility that the missing data mechanism is MAR.

8.9 Concluding remarks

Anaemia constitutes and continues to be a major public health concern in DRC, Uganda and Malawi. Although anaemia prevalence has been reduced in America, Europe, and some Asian countries, it is still higher in Sub-Saharan Africa, in some parts of Asia and even higher in DRC, Uganda and Malawi and little prospect of getting it under control. In addition, the coexistence of other diseases such as malaria, diarrhoea and HIV/AIDS exacerbate the situation even more. It is, therefore, a matter of public health and economic interest, to invest in and organise coordinated, more effective and decisive strategies to fight anaemia together with other coexisting diseases.

In order to be more effective and decisive, strategies against anaemia must be based on in-depth assessment and rational management of risk factors. Dietary information is really important. Behavioural change is not sustainable without regular doses of information. The interventions must be spelt out in comprehensive plans targeting priority high-risk areas, vulnerable communities and families. In particular, all partners such as NGO’s, government health officials, and faith organisations should get involved in spelling out necessary information about the fight against anaemia and should coordinate their plans and activities to the vulnerable communities. This study has shown that anaemia and malnutrition are not a matter of food factors only, but also a matter of non-food factors (such as socioeconomic and demographic and environmental conditions) associated with low food availability. Direct observational and longitudinal studies should be intensified to better understand interactions of different risk factors of anaemia so that there is better appreciation and understanding of the public health concern. In particular, the identification of higher risk areas in DRC, Uganda and Malawi could allow priorities to be identified and plans to be better focused. Efficient and effective educational campaigns, and health workers and health-care providers should be intensified in communities to ensure maximum awareness by both healthcare providers and receivers.

Poverty is undoubtedly a determinant of hunger and the lack of adequate and proper nutrition could be an underlying cause of poverty. Hungry people may find it difficult to build the necessary human, physical and social capital that could enable them to raise their welfare level on a sustainable basis. Fighting hunger will contribute to a reduction in poverty through not only the enhancement of productivity and the reduction of susceptibility to illness, the improvement of school performance but also through a greater willingness to undertake more profitable investments. Poverty reduction is not simply analogous to improving food security. Poverty alleviation, however, will likely promote higher spending in food. Yet, there is no public health measure (in operation) for preventing anaemia of malnutrition among all population groups in DRC, Uganda and Malawi. Few existing public health policies focus on the treatment of anaemia (anaemia control) among vulnerable subgroups such as children below five years old and pregnant women attending antenatal care.

In DRC, Uganda and Malawi, achieving food security, reducing anaemia and increasing proper nutrition require policy considerations whose importance has frequently been underplayed. Plans and activities to reduce anaemia and malnutrition should be integrated into poverty reduction strategy plans as a key element to affordability and to realise the objectives of the post-MDGs.

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Appendix 2.1. List of key words (phrases) used for the literature search

(A) Anaemia	(B) Socioeconomic/demographic determinants of anaemia	(C) Other relevant phrases
Anemia (USA spelling)		
Anaemia definition	Socioeconomic determinants of anaemia	Altitude measure
Anaemia cut off points	Socio-demographic determinants of anaemia	Child welfare
Anaemia in children	Determinants of anaemia in children	Africa
Anaemia in women	Determinants of anaemia in women	Sub-Saharan Africa
Anaemia in the world	Determinants of anaemia in pregnant women	Maternal health
Anaemia in developed countries	Maternal education and anaemia	Child health
Anaemia in less developed countries	Maternal education and maternal health	Infant mortality
Anaemia prevalence in the world	Malnutrition in children	Longitudinal study of anaemia
Anaemia types		
Anaemia related causes		
Anaemia prevention		
Anaemia measures	Maternal smoking habits and child health	Case control study of anaemia
Anaemia and cognitive development		Randomised control trials
Anaemia and learning ability		Cross-sectional
Risk factors of anaemia		Nutritional status and children attending health care
Risk factors of anaemia in children		
Risk factors of anaemia in pregnant women		Child health and the poor
Anaemia in Adults		Experiences and challenges for developing countries
Iron deficiency anaemia and children/women's health		
Anaemia, the basics		Nutritional resilience and positive deviance in child nutrition
Anaemia and Cognitive Function Children		
Iron status of newborns & iron deficiency anaemic mothers	Risk factors of anaemia in children a multilevel analysis	Insecticide treated bed nets and malaria
		All-cause child mortality in an area of intense perennial malaria transmission
Anaemia, Malaria, respiratory distress and complications during pregnancy	Determinants of anaemia among women	
	Maternal education and child nutritional status	Mortality, disability and risk factors of the global burden of diseases
Anaemia with Epoetin Alfa & chronic kidney disease	Maternal education and child health	
Haemoglobin level and Anaemia during pregnancy		A conceptual Framework for Child Survival

Appendix 2.2: Summary table of the literature reviews

N0	Database/Journal	Key words	Author	Title	Year of publication	Geographical area	Type of study
1	Food and Nutrition Bulletin	Risk factors of anaemia in children a multilevel analysis	Ngnie Teta et. Al.	Risk factors for moderate to severe anaemia among children in Benin and Mali: Insights from a multilevel analysis	2007	Benin and Mali	Cross sectional (retrospective)
2	The Journal of Nutrition	Iron deficiency anaemia and children/women's health	Brabin J. B. et. Al.	Iron-deficiency anaemia : re-examining the Nature and magnitude of the Public Health Problem, an Analysis of Anaemia and childhood Mortality	2001	Malawi	A longitudinal study
3	PubMed Central	Determinants of anaemia among women	Amengor Glover, M et. Al.	Determinants of Anaemia in Pregnancy in Sekyere West District, Ghana	2005	Ghana (Sekyere)	Cross sectional
4	Food and Nutrition Bulletin	Determinants of anaemia among women	Ayoya A. M et. al.	Hookworm-Related Anaemia among Pregnant Women: A systematic Review'	2008	Mali	A systematic Review'
5	New England journal of Medicine	Anaemia in children	Calis, Phiri et al. 2008	Severe anaemia in Malawian Children	2008	Malawi	Case-control study
6	Population and Development Review	A conceptual Framework for Child Survival	Mosley, H. and Chen, L	An Analytical Framework for Child Survival in Developing countries	1984	Less developed countries	-
7	WebMed	Anaemia, the basics	Bryg, J.R	Understanding Anaemia-the Basics	2008	Global	Clinical study
8	British Medical Journal	Insecticide treated bed nets and malaria	D'Alessandro, U.	Insecticide Treated Bed nets to prevent Malaria	2001	Africa	Interventional study
9	Science Direct	Maternal	Frost, M et al.	Maternal education and child nutritional status	2005	Bolivia	Cross sectional

10	JSTOR	education and child nutritional status	Desai, S. & Alva	Maternal education and child health: Is there a strong Causal relationship?	1998	Less developed countries	Cross sectional
11	Nutrition and Public Health	Maternal education and child health	Handa, R. et al.	Effects of Anaemia on Cognitive Function Children	2009	India	Cross sectional
12	American Journal of Tropical Medicine & Hygiene	Anaemia and Cognitive Function Children	Eisele, T.P, et al.	Effect of sustained insecticide-treated bed net use on all-cause child mortality in an area of intense perennial malaria transmission in western Kenya	2005	Kenya	Cross sectional
13	Journal of Tropical Paediatrics	All-cause child mortality in an area of intense perennial malaria transmission	Hokama, T., S. et al.	Iron status of newborns born to iron deficiency anaemic mothers	1996	Japan	Clinical trials
14	American Journal of Tropical Medicine & Hygiene	Iron status of newborns & iron deficiency anaemic mothers	Murphy, S.J & Breman	Gaps in the Childhood Malaria Burden in Africa: Cerebral Malaria, Neurological Sequelae, Anaemia, Respiratory Distress, Hypoglycemia, and Complications ofPregnancy	2001	Africa	Literature Reviews
15	PubMed	Anaemia , Malaria, respiratory distress and complications during pregnancy	Murray C. & Lopez	Global Mortality, Disability, and the contribution of risk Factors: Global Burden of Diseases study	1997	Worldwide	-
16	Pubmed	Mortality, disability and risk factors of the global burden of diseases	Radi, S. et al.	Nutritional Status of Palestinian Children attending primary Health Care Centre in Gaza	2009	Palestine (Gaza)	Cross sectional
17	PubMed	Nutritional status and children	Singh, A.K et al.	Correction of Anaemia with Epoetin Alfa in Chronic Kidney Disease	2006	USA	Clinical Trials

		attending health care					
18	American Journal of Tropical Medicine & Hygiene	Anaemia with Epoetin Alfa & chronic kidney disease	Tolentino, K & Frienman, J.F	An Update on anaemia in Less Developed Countries	2007	Less Developed Countries	Literature reviews
19	American Journal of Health	Anaemia in less developed countries	Wagstaff, A. Bustreo et al.	Child health: Reaching the Poor	2004	Less Developed Countries	Literature reviews
20	PubMed	Child health and the poor	Xing, Y, Yan et al.	Haemoglobin levels and Anaemia during pregnancy in the highlands Tibet: a Hospital-Based study	2009	Tibet (China)	Cross sectional
21	The Journal of Nutrition	Haemoglobin level and Anaemia during pregnancy	Yip, R & Ramakrishnan	Experiences and challenges in developing countries	2002	Developed and developing countries	Literature reviews
22	Inter Sciences	Experiences and challenges for developing countries	Zeitlin, M	Nutritional Resilience in Hostile Environment: Positive Deviance in Child Nutrition	1991	-	Clinical trials
		Nutritional resilience and positive deviance in child nutrition					

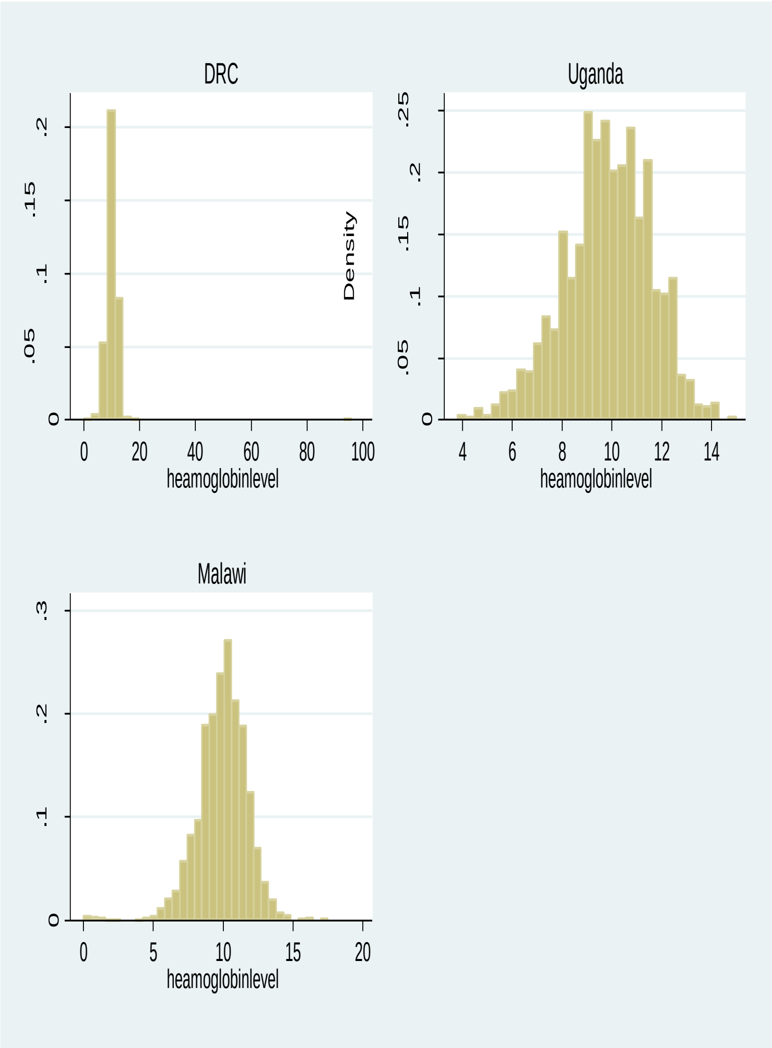
Appendix 3.1 The ranges of haemoglobin values for children and women by country

	DRC 2007		Uganda 2006		Malawi 2004		Malawi 2010
	Children	Women	Children	Women	Children	Women	Women
Min	1.0	0.9	3.8	2.2	1.0	0.6	2.9
Max	18.8	17.5	15.0	17.5	17.5	16.8	19.0
Excluded (outside normal ranges)	4.0	5.0	0.0	0.0	5.0	0.0	1.0
Missing values	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Sample size	3,159	4,632	2,110	2,817	2,329	2,749	7,290

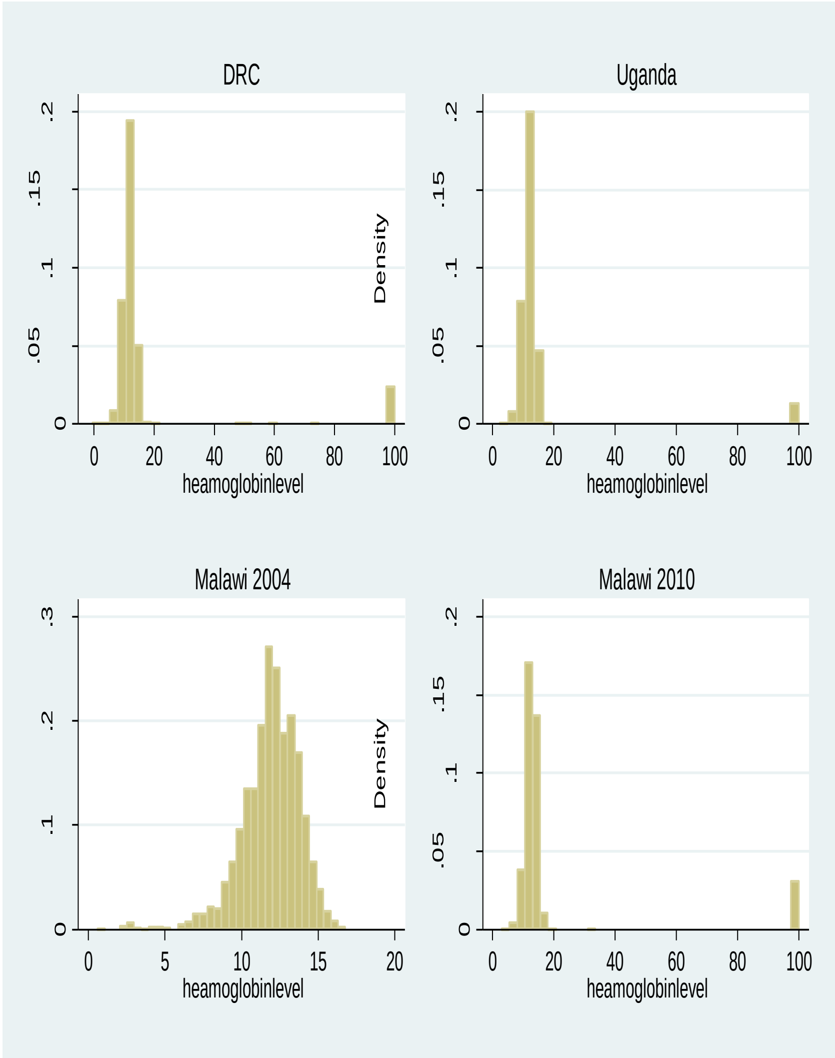
Appendix 3.2 The ranges of weight-for-age values for children by country

	DRC 2007	Uganda 2006	Malawi 2004
Min	-8.6	-5.1	-8.2
Max	9.0	5.3	6.8
Excluded (outside normal ranges)	380	150	200
Missing values	300	174	896
Total Sample size	2,479	1,786	1,233

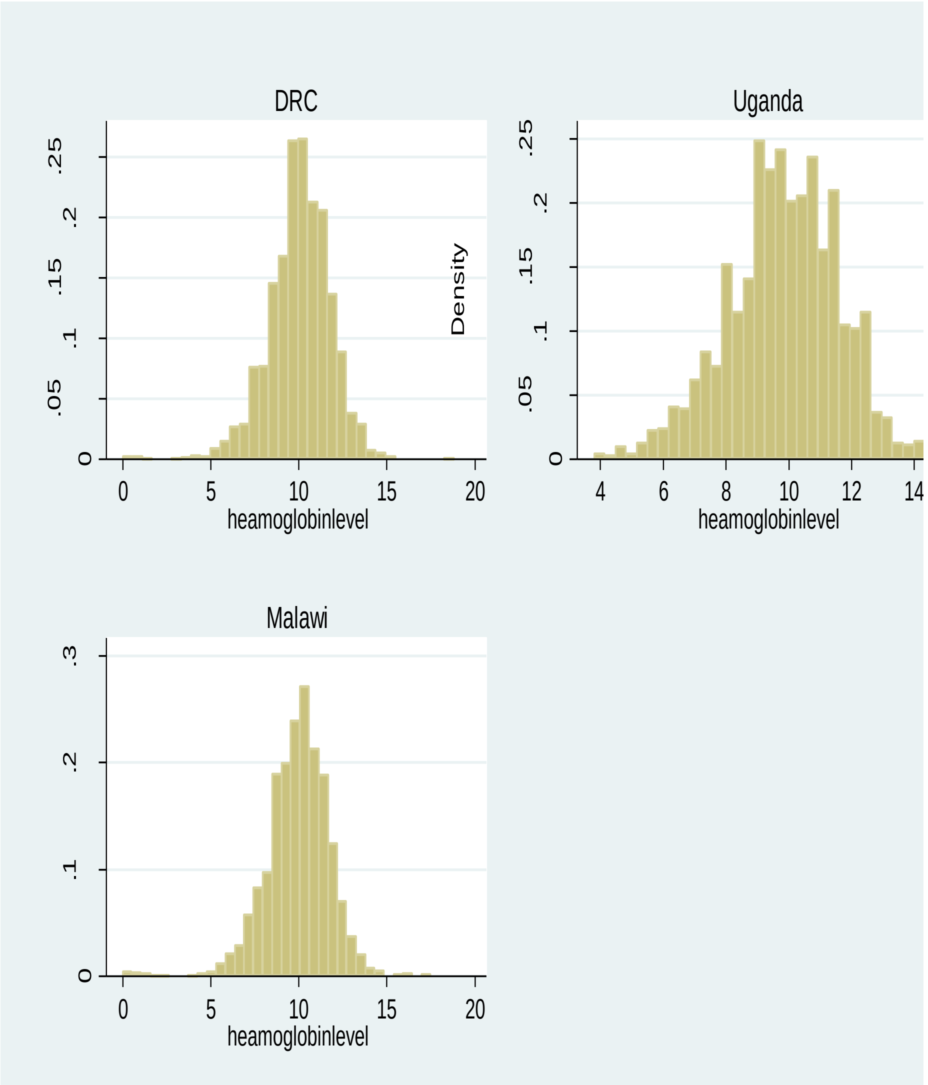
Appendix 3.3 Histogram of heamoglobin values for children before excluding outlying ranges



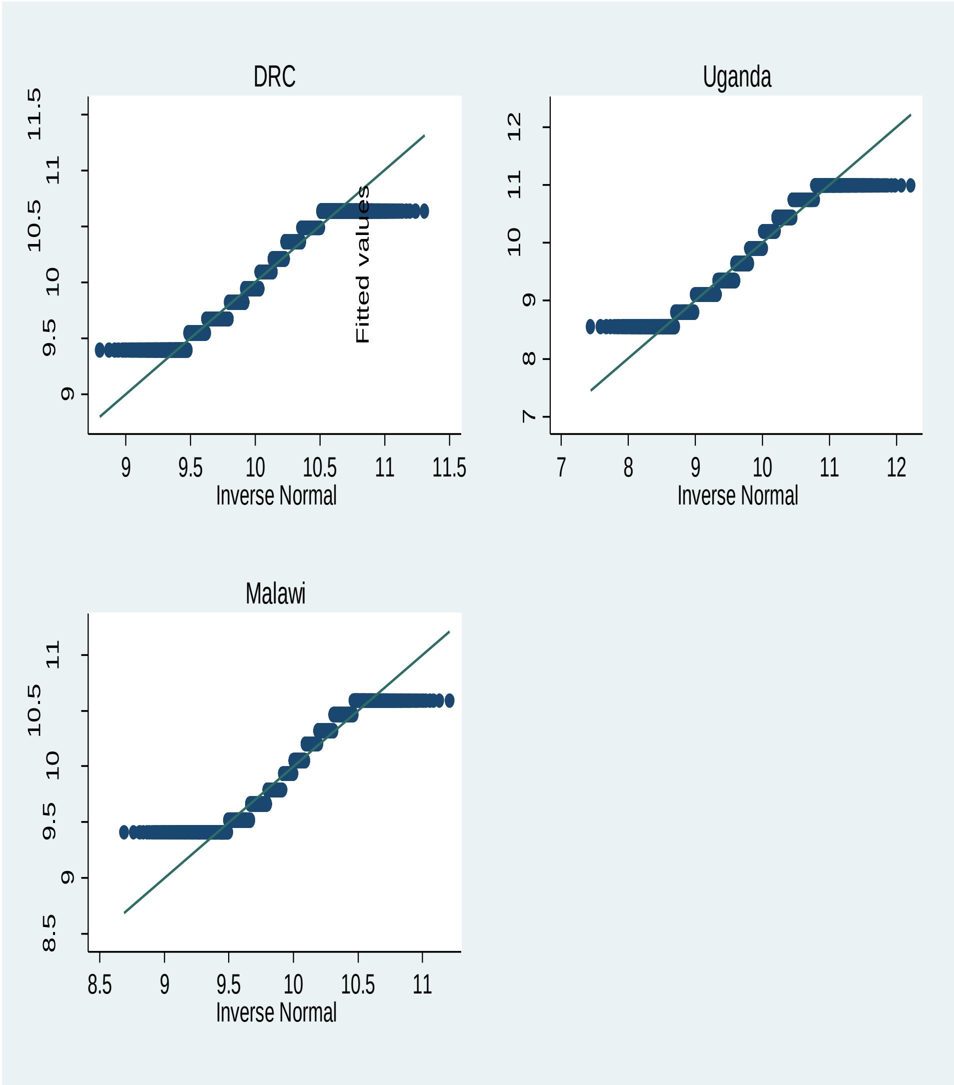
Appendix 3.4 Histogram of heamoglobin values for women before excluding outlying ranges



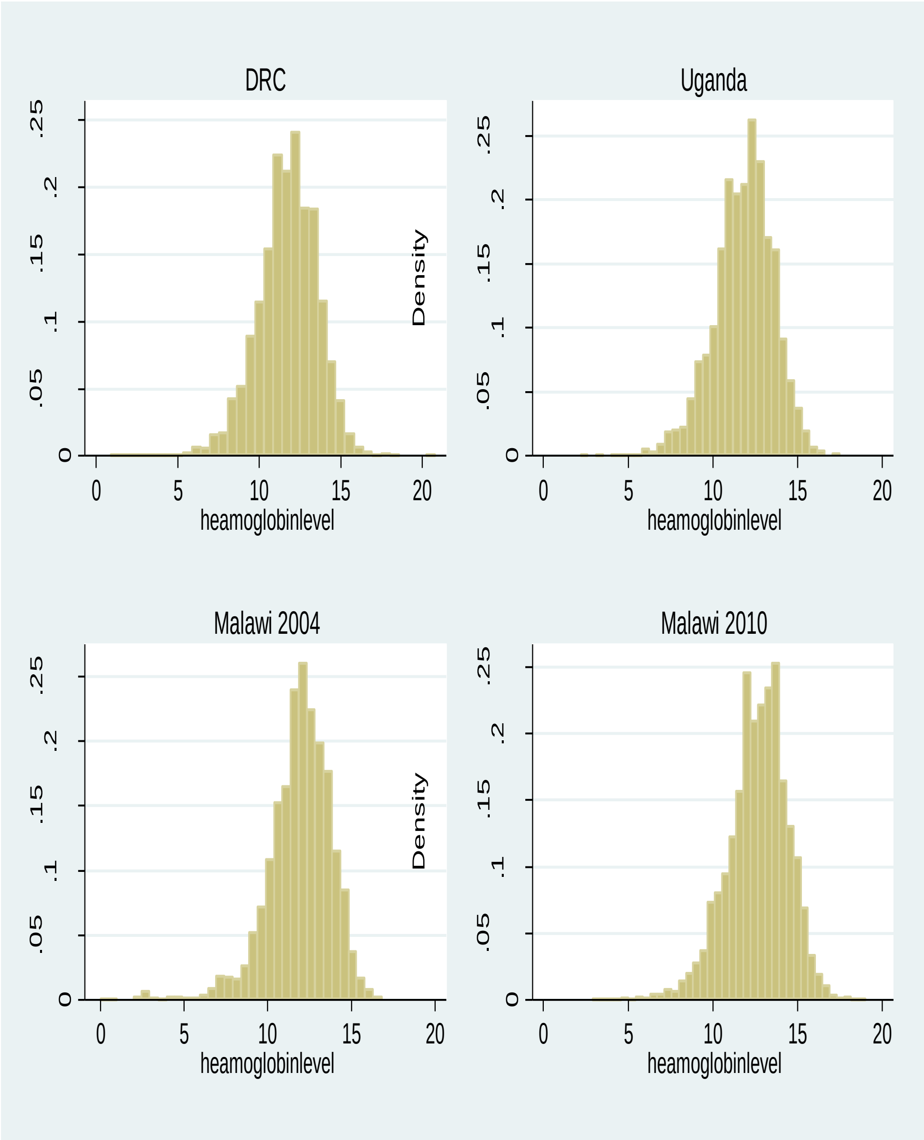
Appendix 3.5 Histogram of children's heamoglobin levels by country after exclusions due to outlying values



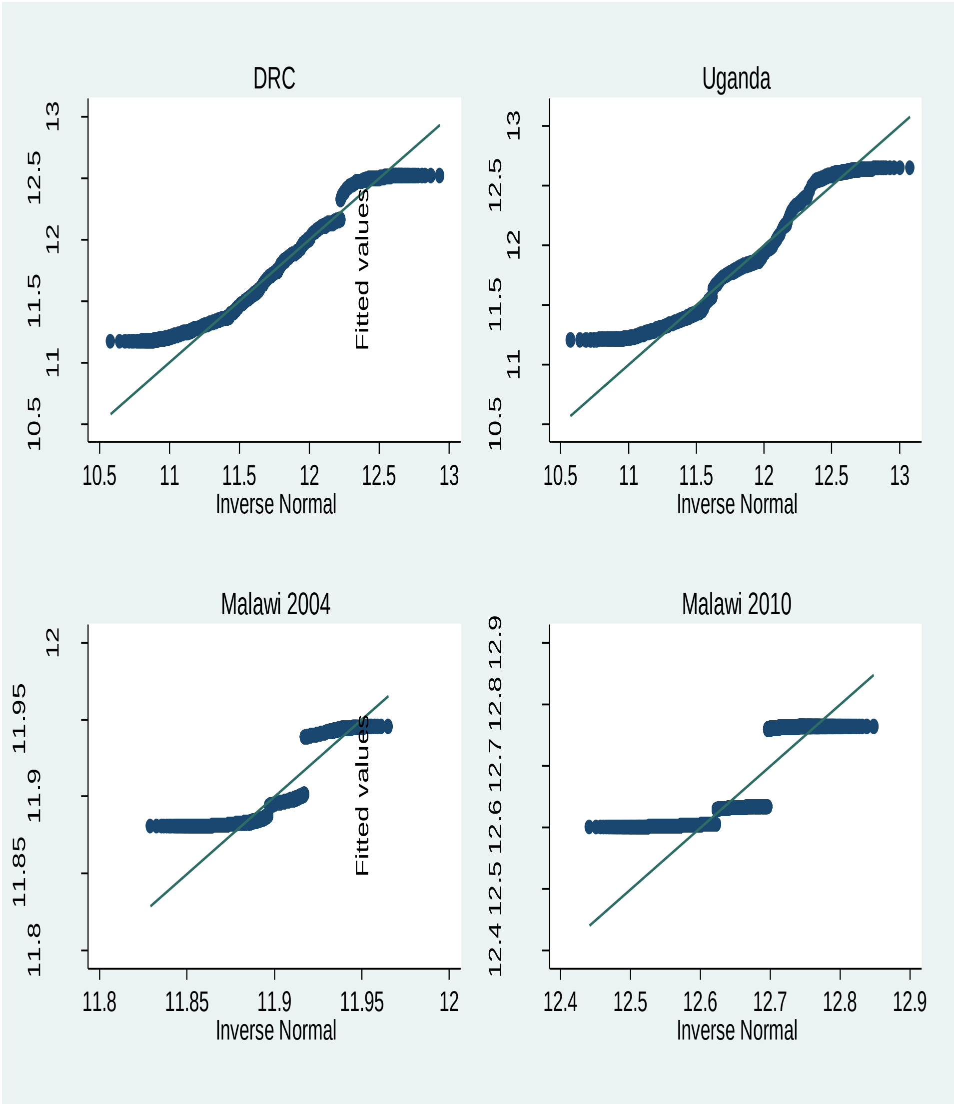
Appendix 3.6 Residual plots before categorising children's heamoglobin level



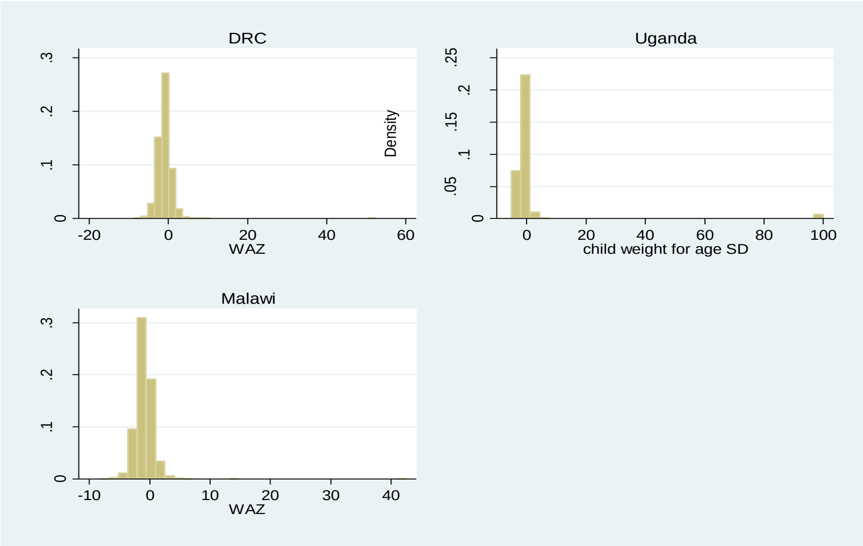
Appendix 3.7 Histogram of women's heamoglobin levels by country after exclusions due to outlying values



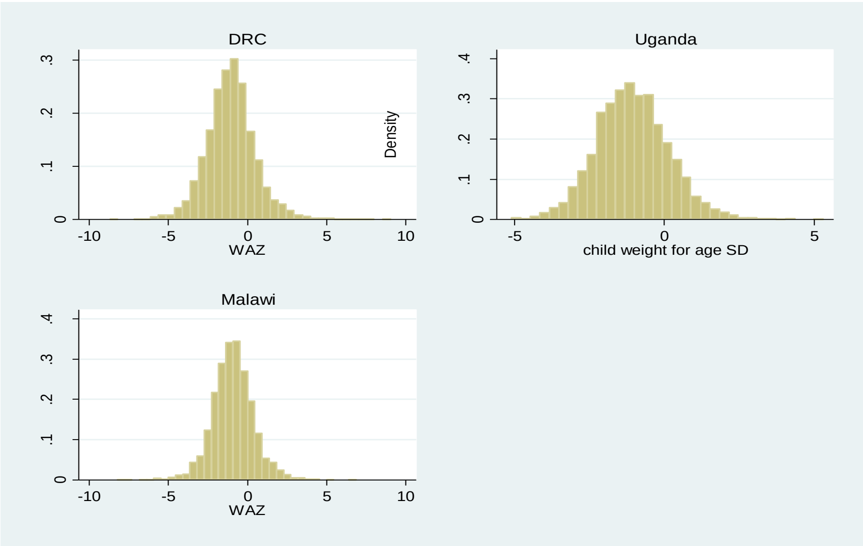
Appendix 3.8 Residual plots before categorising women's heamoglobin level by country



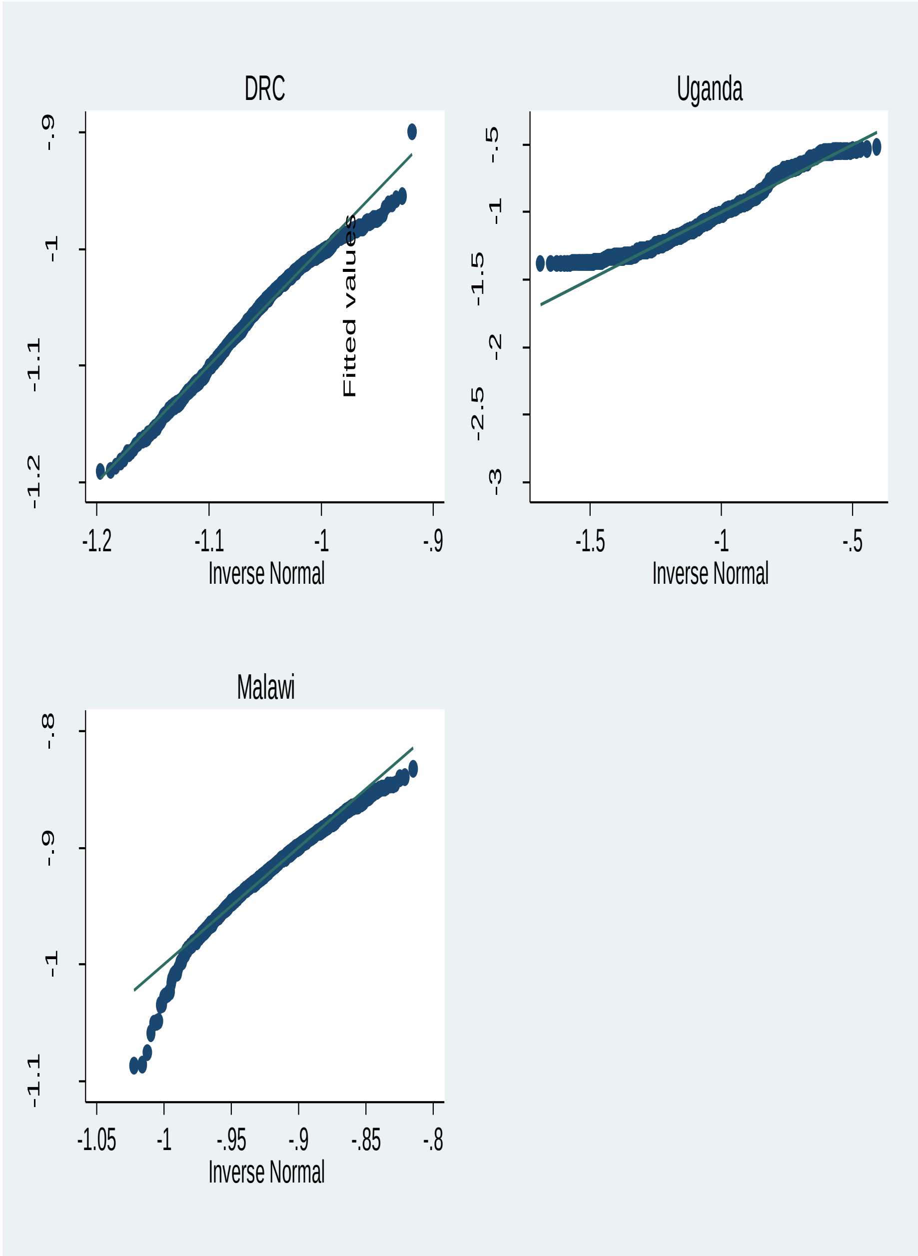
Appendix 3.9 Histograms of weight-for-age z-scores before excluding outlying values



Appendix 3.10 Histograms of weight-for-age z-scores after excluding outlying values



Appendix 3.11 Residual plots with weight-for-age z-scores as the outcome before modeling

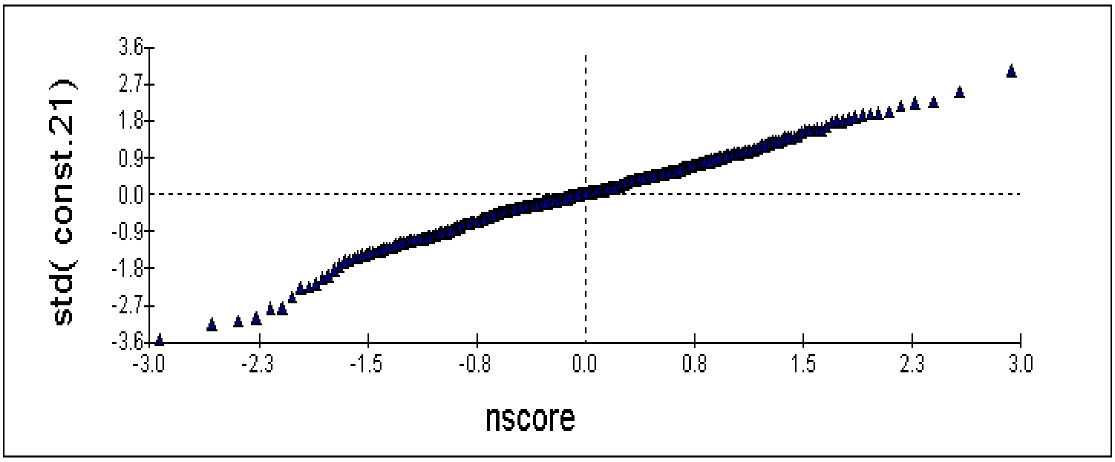


Appendix 4.1. Estimates and odds ratio of multilevel ordinal regression models for anaemia in children

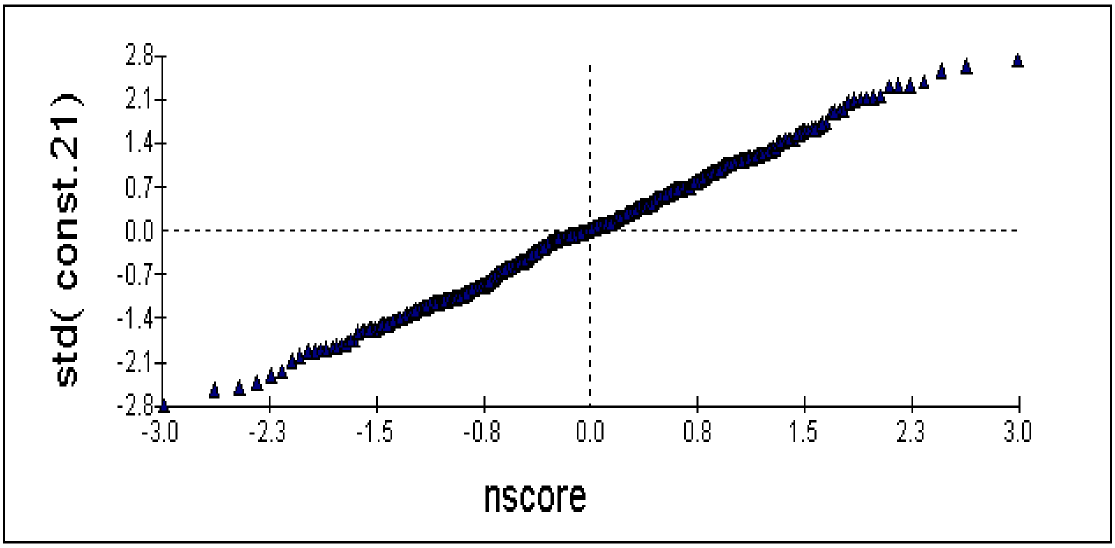
	DRC					**Uganda**					**Malawi**					**All together**				
Variable	**Estimate**	**S.E**	**O.R**	**95% C.I**		**Estimate**	**S.E**	**O.R**	**95% C.I**		**Estimate**	**S.E**	**O.R**	**95% C.I**		**Estimate**	**S.E**	**O.R**	**95% C.I**	
Fixed Part																				
Constant																				
Not anaemic (Ref)																				
Mild	-1.11	0.147				-1.689	0.214				-1.200	0.08				-1.270	0.093			
Moderate & severe	0.957	0.147				0.686	0.211				0.942	0.079				0.877	0.093			
Individuals factors																				
Age																				
<2 years(Ref)			1.00					1.00					1.00					1.00		
2-5 years	**-0.322**	0.07	0.73	0.636	0.84	**-0.388**	0.086	0.68	0.58	0.81	**-0.120**	0.079	0.89	0.76	1.04	**-0.260**	0.048	0.65	0.70	0.85
Sex																				
Female(Ref)			1.00					1.00					1.00					1.00		
Male	**0.156**	0.068	1.17	1.02	1.34	**0.158**	0.084	1.17	0.99	1.38	0.015	0.078	1.01	0.87	1.18	**0.113**	0.044	1.12	1.03	1.22
Birth weight																				
Normal(Ref)			1.00					1.00					1.00					1.00		
High	**0.542**	0.204	1.72	1.15	2.56	0.105	0.240	1.11	0.69	1.77	0.115	0.240	1.12	0.70	1.80	0.251	0.134	1.29	0.99	1.67
Low	0.091	0.164	1.10	0.79	1.51	-0.254	0.255	0.77	0.47	1.27	-0.254	0.205	0.78	0.52	1.16	-0.100	0.113	0.90	0.72	1.12
Not weighed	**0.241**	0.089	1.27	1.07	1.52	-0.031	0.102	0.96	0.79	1.18	-0.131	0.102	0.88	0.72	1.07	0.103	0.064	1.11	0.98	1.26
Community factors																				
Drinking water																				
Others(Ref)			1.00					1.00					1.00					1.00		
Piped	-0.108	0.075	0.90	0.77	1.04	**-0.962**	0.306	0.38	0.21	0.69	**-0.720**	0.234	0.49	0.31	0.77	**-0.320**	0.115	0.73	0.58	0.91
Other factors																				
Mother anaemia status																				
Not anaemic (Ref)			1.00					1.00					1.00					1.00		
Anaemic	**0.169**	0.071	1.18	0.85	1.65	**0.226**	0.087	1.25	1.06	1.49	**0.194**	0.081	1.21	1.04	1.42	**0.217**	0.045	1.24	1.14	1.36
Had fever																				
No (Ref)			1.00					1.00					1.00					1.00		
Yes	-0.058	0.075	0.94	0.81	1.09	0.086	0.088	1.09	0.92	1.29	**0.181**	0.082	1.20	1.02	1.41	0.068	0.047	1.07	0.98	1.17
Country																				
DRC(Ref)																		1.00		
Uganda		NA					NA					NA				-0.100	0.066	0.90	0.79	1.03
Malawi																0.046	0.072	1.05	0.91	1.21
Random Part																				
Community	0.147	0.041				0.076	0.049				0.000	0.000				0.130	0.026			
Household	0.032	0.074				0.000	0.000	-			0.027	0.082				0.000	0.000			
Women	0.000	0.000	-			0.000	0.000	-			0.000	0.000	-			0.000	0.000			

S.E : Standard error; C.I : confidence interval ;OR: Odd Ratios & Ref: reference category; Bold indicates a significant difference ,NA: not applicable

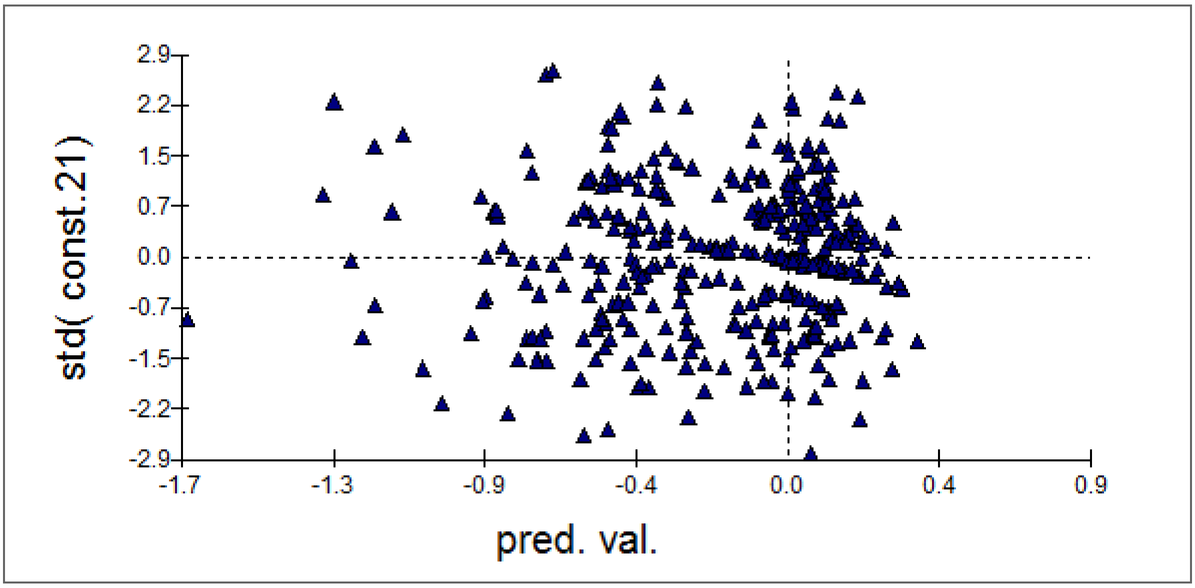
Appendix 4.2. Normal probability plot of community residuals for anaemia in children in DRC



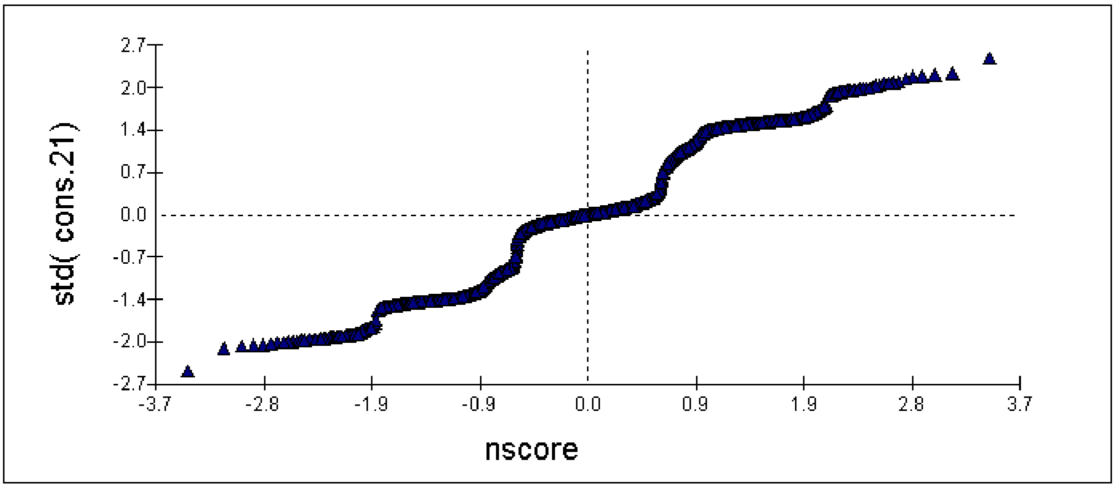
Appendix 4.3. Normal score plot of community residuals for anaemia in children in Uganda



Uganda



Appendix 4.4. Normal score plot of community residuals for anaemia in children in Malawi



Appendix 5.1. Estimated mean weight-for-age for anaemia children in DRC, Uganda and Malawi

Variable	Congo				Uganda				Malawi			
	Weight_for-age(a) Anaemia Yes		**Weight_for-age OLS(b)** Anaemia Yes		**Weight_for-age(a)** Anaemia Yes		**Weight_for-age OLS(b)** Anaemia Yes		**Weight_for-age(a)** Anaemia Yes		**Weight_for-age OLS(b)** Anaemia Yes	
	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
Constant	-0.497	0.157	-0.919	0.138	-1.800	0.140	-1.213	0.121	-0.875	0.224	-0.661	0.195
Age												
<2 years(Ref)												
2-5 years	**-0.300*** **	0.073	**-0.492*** **	0.064	**-0.693*** **	0.066	0.196	0.134	-0.228	0.144	-0.150	0.137
Sex												
Female(Ref)												
Male	**-0.235*** **	0.065	**-0.167*** **	0.061	**0.016***	0.070	-0.049	0.064	-0.125	0.083	**-0.135***	0.080
Maternal education												
None (Ref)												
Primary	-0.014	0.085	0.034	0.079	**0.149****	0.086	**0.151****	0.079	-0.025	0.098	-0.022	0.096
Secondary	**0.384*** **	0.093	**0.356*** **	0.086	**0.329****	0.137	**0.331*** **	0.127	0.027	0.163	0.114	0.154
Breastfeeding												
No(Ref)												
Yes	-0.087	0.077	-0.093	0.072	-0.017	0.084	**-0.189****	0.077	0.011	0.140	-0.021	0.135
Mother anaemic												
No(Ref)												
Yes	**-0.282*** **	0.069	**-0.111***	0.062	**0.150****	0.072	-0.016	0.065	-0.105	0.090	-0.179	0.081
Vegetables												
No(Ref)												
Yes	0.051	0.078	0.007	0.071	**-0.300*** **	0.075	**-0.275*** **	0.069	-0.082	0.092	-0.109	0.088
Red meat												
No (Ref)												
Yes	-0.006	0.076	0.048	0.073	0.151	0.103	0.087	0.105	0.112	0.089	0.069	0.085
Wealth												
Poorest (Ref)												
Below average	0.012	0.106	-0.096	0.098	0.106	0.103	0.154	0.094	-0.176	0.142	-0.088	0.131
Average	0.104	0.104	0.104	0.096	-0.055	0.106	0.034	0.098	0.009	0.139	0.105	0.129
Above average	**0.262****	0.106	**0.166***	0.098	-0.002	0.112	0.024	0.103	-0.180	0.136	-0.079	0.124
Wealthiest	**0.326***	0.108	**0.254****	0.100	0.181	0.128	**0.317*** **	0.119	-0.262	0.159	-0.167	0.149
Region												
Rho 1	**-0.681**	**0.059**			**0.764**	**0.045**			**0.496**	**0.200**		

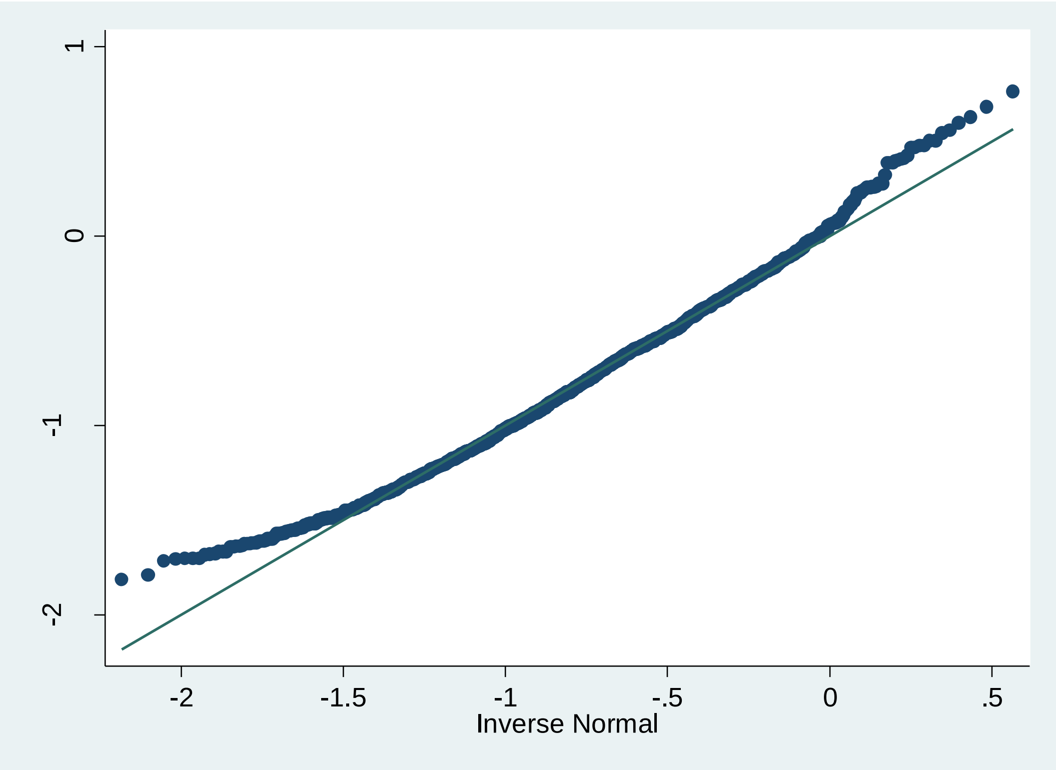
*(a)Estimates from endogenous switching regression models; (b) Estimates from the standard ordinary Least Square regression model; Coef: coefficient ; SE: standard error; Ref: reference category; ***: p< at 1% ** : p< at 5% *:p< at 10%*

Appendix 5.2. Estimated mean weight-for-age for no anaemia children in DRC, Uganda and Malawi

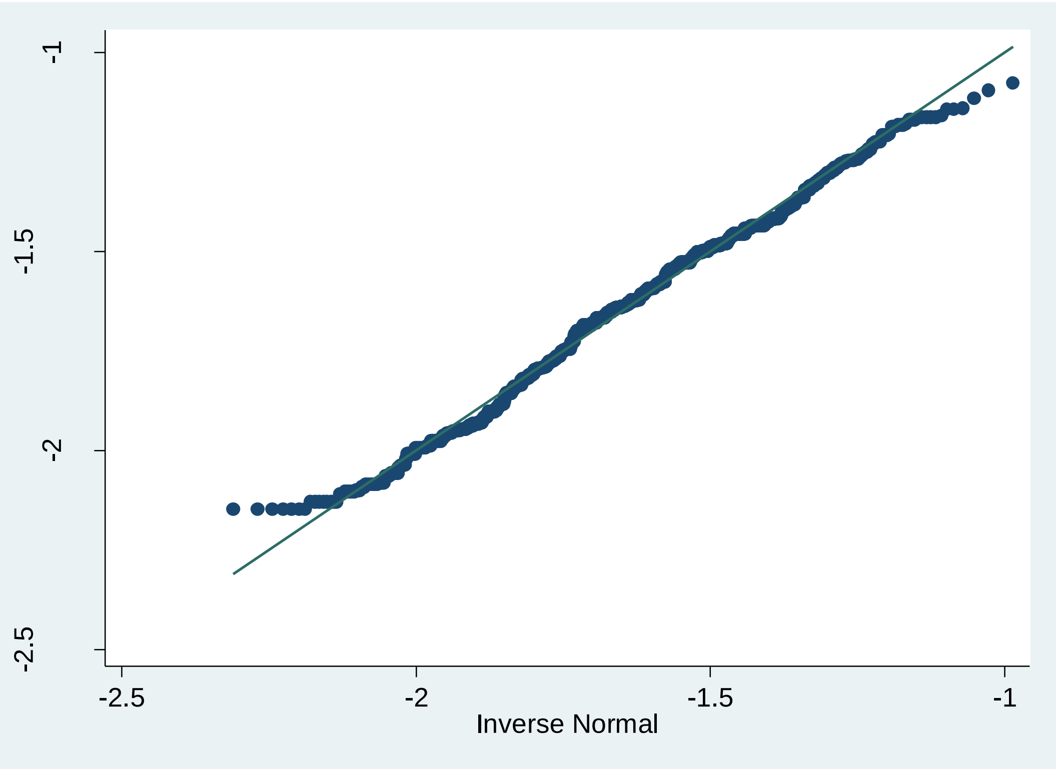
	Congo				Uganda				Malawi			
Variable	**Weight_For-age(a)** Anaemia No		**weight_For-age OLS(b)** Anaemia No		**weight_For-age(a)** Anaemia No		**weight_For-age OLS(b)** Anaemia No		**weight_For-age(a)** Anaemia No		**weight_For-age OLS(b)** Anaemia No	
	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE	Coef	SE
Constant	-2.098	0.565	-1.238	0.231	-0.720	0.306	-1.208	0.231	0.971	0.213	-0.499	0.447
Age												
<2 years(Ref)												
2-5 years	-0.025	0.186	**-0.262****	0.112	**-0.693*****	0.066	0.196	0.134	-0.304	0.139	-0.137	0.269
Sex												
Female(Ref)												
Male	**-0.251****	0.108	**-0.185****	0.098	-0.017	0.115	-0.041	0.114	0.032	0.083	-0.018	0.161
Maternal education												
None (Ref)												
Primary	0.095	0.133	0.164	0.124	-0.003	0.146	0.008	0.147	-0.012	0.101	**-0.388 ***	0.209
Secondary	**0.353*****	0.137	**0.324****	0.131	0.351	0.220	0.375	0.221	-0.280	0.148	-0.193	0.279
Breastfeeding												
No(Ref)												
Yes	-0.094	0.117	-0.090	0.114	**-0.238***	0.125	**-0.276***	0.124	0.097	0.141	-0.146	0.268
Mother anaemic												
No(Ref)												
Yes	-0.225	0.149	-0.039	0.099	0.079	0.123	0.022	0.117	**0.283*****	0.085	-0.050	0.170
Vegetables												
No(Ref)												
Yes	0.052	0.116	**0.212****	0.107	-0.115	0.118	-0.107	0.206	0.091	0.095	-0.087	0.193
Red meat												
No (Ref)												
Yes	**0.190***	0.112	0.054	0.112	-0.092	0.205	-0.114	0.119	**0.190****	0.090	0.020	0.186
Wealth												
Poorest (Ref)												
Below average	**0.293***	0.172	0.188	0.155	0.237	0.181	0.261	0.182	**-0.346****	0.153	0.167	0.333
Average	0.152	0.174	0.175	0.170	0.196	0.182	0.250	0.180	**-0.400*****	0.148	-0.069	0.325
Above average	**0.519*****	0.170	**0.432*****	0.159	0.279	0.195	0.301	0.196	**-0.410*****	0.143	0.071	0.312
Wealthiest	0.188	0.172	0.123	0.162	**0.393***	0.208	**0.473*****	0.202	**-0.366****	0.165	0.118	0.351
Region												
Rho 1	-0.448	0.267			0.248	0.163			**-0.875**	**0.049**		

(a)Estimates from endogenous switching regression models;
(b) Estimates from the standard ordinary Least Square regression model
*Coef: coefficient ; SE: standard error; Ref: reference category; *** : p< at 1% ** : p< at 5% *:p< at 10%*

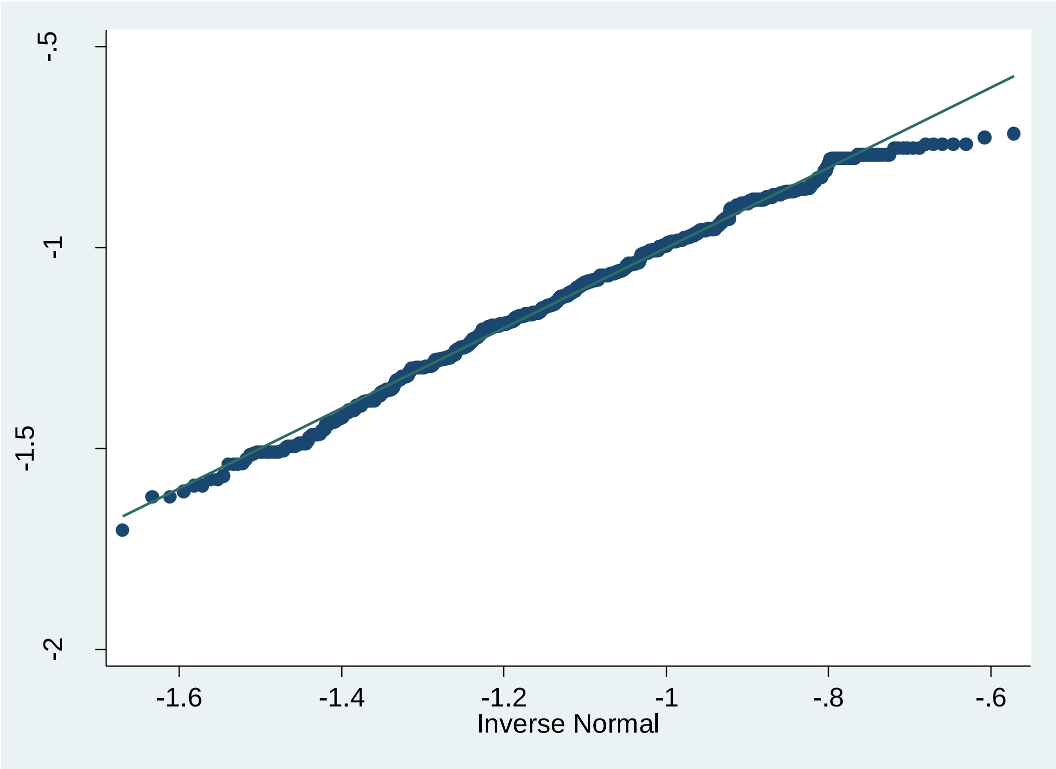
Appendix 5.3. The joint normality of the error terms for DRC model.



Appendix 3.4. The joint normality of the error terms for Uganda's model.

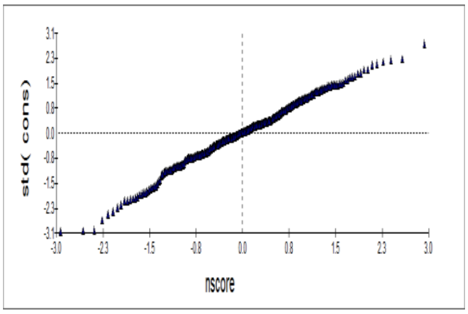


Appendix 5.5. The joint normality of the error terms for Malawi's model.

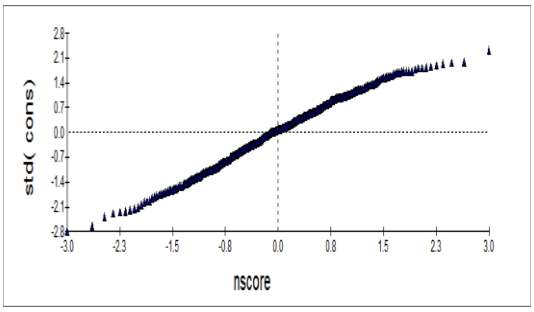


Appendix 6.1. Residuals plots at community level

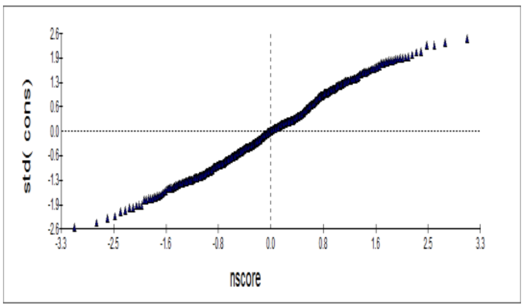
DRC



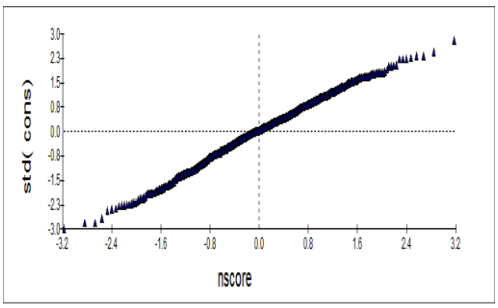
Uganda



Malawi



All



Appendix 6.2. Factors associated with anaemia for pregnant and non-pregnant women by country

Variable	DRC		Uganda		Malawi	
	Pregnant	**Non-pregnant**	**Pregnant**	**Non-pregnant**	**Pregnant**	**Non-pregnant**
Current age	NS	S	NS	NS	NS	S
Parity	S	NS	NS	NS	NS	NS
BMI	NS	S	NS	S	NS	S
Breastfeeding	NS	NS	NS	S	NS	NS
Occupation	NS	NS	NS	NS	NS	NS
Education	NS	S	NS	NS	NS	NS
Marital status	NS	NS	NS	S	NS	NS
Partner education	NS	S	NS	NS	NS	S
Bed net use	NS	NS	NS	NS	NS	NS
Wealth status	NS	S	NS	NS	NS	NS
Place of residence	S	S	NS	S	NS	NS
Water source	NS	S	NS	NS	NS	NS
Region	S	S	NS	S	NS	NS

Appendix 6.3. Odds Ratio and 95% C.I of anaemia for pregnant and non-pregnant women by country

		DRC						Uganda						Malawi					
		Pregnant			Non-pregnant			Pregnant			Non-pregnant			Pregnant			Non-pregnant		
		O.R	95% C.I		O.R	95% C.I		O.R	95% C.I		O.R	95% C.I		O.R	95% C.I		O.R	95% C.I	
Current age	15-24	1.00			1.00			1.00			1.00			1.00			1.00		
	25-34	0.94	0.61	1.46	1.17	0.98	1.40	0.92	0.53	1.61	0.95	0.75	1.20	1.32	0.79	2.20	1.09	0.87	1.36
	35+	0.59	0.32	1.05	**1.24**	1.02	1.50	0.96	0.43	2.15	1.12	0.86	1.45	0.90	0.40	2.06	**1.31**	1.01	1.69
Parity	Zero	1.00			1.00			1.00			1.00			1.00			1.00		
	One	1.28	0.78	2.09	1.19	0.97	1.46	1.06	0.51	2.20	0.94	0.72	1.23	1.01	0.58	1.76	1.08	0.83	1.40
	Two	**1.79**	1.01	3.15	1.03	0.80	1.31	1.01	0.46	2.19	0.82	0.59	1.13	0.87	0.43	1.76	1.01	0.73	1.40
	Three+	2.56	0.87	7.52	1.05	0.75	1.47	7.81	0.81	75.47	0.86	0.56	1.32	1.06	0.06	19.28	1.00	0.59	1.71
BMI	Low	1.00			1.00			1.00			1.00			1.00			1.00		
	Normal	0.98	0.61	1.58	0.91	0.79	1.05	1.87	0.95	3.68	0.87	0.72	1.05	1.68	0.81	3.49	0.96	0.79	1.16
	Overweight	0.92	0.48	1.8	**0.73**	0.57	0.93	1.22	0.52	2.87	0.74	0.54	1.00	1.96	0.81	4.72	**0.63**	0.45	0.86
	Obese	0.57	0.53	3.20	**0.62**	0.41	0.96	4.54	0.30	69.15	**0.39**	0.23	0.67	0.35	0.03	3.50	0.57	0.33	1.01
Breastfeeding	No	1.00			1.00			1.00			1.00			1.00			1.00		
	Yes	0.61	0.3	1.24	1.06	0.86	1.29	0.60	0.26	1.39	**1.43**	1.10	1.84	0.75	0.33	1.68	0.86	0.67	1.11
Education	None	1.00			1.00			1.00			1.00			1.00			1.00		
	Primary	1.11	0.67	1.84	0.85	0.71	1.03	0.92	0.46	1.82	1.00	0.79	1.26	1.03	0.56	1.87	0.99	0.80	1.24
	Secondary+	1.56	0.83	2.92	**0.76**	0.61	0.94	1.20	0.43	3.33	1.09	0.80	1.50	1.09	0.42	2.86	1.04	0.73	1.48
Marital status	Never married	1.00			1.00			1.00			1.00			1.00			1.00		
	Married	0.76	0.17	3.4	0.93	0.63	1.38	0.56	0.10	3.31	1.48	0.84	2.60	1.20	0.11	1.36	1.47	0.52	4.17
	Widowed	0.85	0.12	6.08	1.11	0.74	1.67	7.59	0.49	16.90	**1.79**	1.01	3.17	1.30	0.10	1.96	1.85	0.65	5.24
Partner education	None	1.00			1.00			1.00			1.00			1.00			1.00		
	Primary	1.19	0.54	2.6	**1.60**	1.21	2.11	0.65	0.26	1.62	0.93	0.67	1.29	1.18	0.60	2.33	0.96	0.73	1.25
	Secondary+	1.39	0.63	3.07	**1.36**	1.04	1.78	0.62	0.22	1.77	0.91	0.63	1.31	0.79	0.35	1.79	**0.68**	0.48	0.95
	No Partner	1.06	0.28	4.09	1.36	0.91	2.04	0.75	0.18	3.05	1.01	0.57	1.77	1.30	0.11	2.96	1.36	0.48	3.79
Wealth status	Poorest	1.00			1.00			1.00			1.00			1.00			1.00		
	Poorer	0.9	0.5	1.63	0.88	0.71	1.09	0.81	0.34	1.90	1.14	0.86	1.51	1.02	0.47	2.22	0.97	0.73	1.28
	Middle	0.93	0.5	1.73	0.98	0.79	1.22	0.62	0.27	1.41	1.07	0.81	1.40	0.94	0.45	2.00	1.00	0.75	1.34
	Richer	0.77	0.4	1.5	0.97	0.77	1.21	0.99	0.44	2.23	1.06	0.81	1.38	1.02	0.49	2.11	0.97	0.73	1.29
	Richest	0.93	0.48	1.82	**0.78**	0.62	0.99	1.06	0.43	2.59	1.04	0.78	1.38	1.37	0.58	3.24	1.10	0.79	1.52

		DRC						Uganda						Malawi					
		Pregnant			Non-pregnant			Pregnant			Non-pregnant			Pregnant			Non-pregnant		
		O.R	95% C.I		O.R	95% C.I		O.R	95% C.I		O.R	95% C.I		O.R	95% C.I		O.R	95% CI	
Place of residence	Rural	1.00			1.00			1.00			1.00			1.00			1.00		
	Urban	**0.56**	0.34	0.91	**0.72**	0.61	0.86	0.56	0.20	1.55	**0.66**	0.46	0.94	0.55	0.24	1.27	0.86	0.64	1.15
Water source	Other	1.00			1.00			1.00			1.00			1.00			1.00		
	Piped	2.08	0.85	5.05	**1.37**	1.07	1.76	0.67	0.11	4.15	0.98	0.62	1.55	1.31	0.32	5.42	0.88	0.57	1.36
Region		S			S			NS			S			NS			NS		

Appendix 6.3. continue..; ***Figures in bold indicate statistically significant; O.R: Odds ratio; C.I: Confidence intervals***