# Environmental Health Hazards and Under-Five Mortality in Sub-Saharan Africa: Analysis Using Multilevel Discrete-Time Hazard Model

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# ABSTRACT

Environmental health hazards are pathogens and chemicals in the environment, which can cause health problems. The importance of such environmental factors in child health and survival are acknowledged in the literature. However, empirical researches on the effect of environmental health hazards on child health and survival are rare in sub-Saharan Africa. This study assesses the effect of household environmental health hazards on under-five mortality in sub-Saharan Africa. The study has used DHS data sets of the following 12 countries in the region: Burkina Faso, Burundi, Cameroon, Cote d'Ivoire, Ethiopia, Gabon, Guinea, Malawi, Niger, Rwanda, Senegal and Zimbabwe. These countries constitute roughly 26 per cent of the region's population.

The study has employed principal component method to construct an index of the level of household environmental health hazards using the following indicators: water source, type of toilet facility, flooring material, type of wall, type of roof, type of cooking fuel and location of water source. I have used a multilevel discrete-time hazard model to assess the relationship between the environmental index and under-five mortality after controlling for the effects of a number of socioeconomic, bio-demographic and community-level characteristics.

The study indicates that an assessment of the effects of household environmental health hazards on under-five mortality without taking into account for interaction between the environment and the age of the child undermines the importance of environmental factors. More specifically, the study has found a significant effect of the index of household environmental health hazards on under-five mortality in three countries: Burundi, Niger and Rwanda. By contrast, an assessment of interaction effects indicates that its effect on the risk of death depends on the age of the child in eight countries: Burkina Faso, Burundi, Cameroon, Guinea, Malawi, Niger, Rwanda and Senegal. An increase in the index of household environmental health hazards is consistently associated with increase in risk of death during 24-59 months after birth. For a unit increase in the index of household environmental health hazards, the odds of risk of death increases by 18 per cent in Burkina Faso to 33 per cent in Senegal for this age interval. Its effect is less noticeable among young children.

The study concludes that improvement in household environmental conditions can reduce the risk of mortality during late childhood. Therefore, policies and

interventions which aim to improve environmental health should make use of this differential effect for better success in the region.

**Key words:** Household environmental health hazards, Under-five mortality, Community effects, Multilevel discrete-time hazard model, Sub-Saharan Africa.

# DECLARATION

I hereby declare that I have acknowledged all sources of information that I have used for my thesis as required by the rules. To the best of my knowledge, I have not made any copies of others work or present others' ideas without the proper citation.

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## ACRONYMS AND ABREVAIATIONS

**AfDB** : African Development Bank

**AIDS**: Acquired Immune Deficiency Syndrome

**ARI**: Acute Respiratory Infections

**AU**: African Union

**BCG**: Bacillus Calmette–Guérin

**CI**: Confidence Interval

**DHS**: Demographic and Health Survey

**DPT**: Diphtheria, Pertussis, and Tetanus

**GDP**: Gross Domestic Product

**GNP**: Gross National Product

**HIV**: Human Immuno-deficiency Virus

**ICC**: Intra-Class Correlation

**MDG**: Millennium Development Goal

**OLS:** Ordinary Least Square

**OR**: Odds Ratio

**PRB:** Population Reference Bureau

**Stdv:** Standard deviation

**U5MR**: Under-five Mortality Rate

**UNDP**: United Nations Development Programme

**UNECA**: United Nations Economic Commission for Africa

**UNICEF**: United Nations Children's Fund

**UN-IGME**: UN Inter-agency Group for Child Mortality Estimation

**WHO**: World Health Organization

# 1. INTRODUCTION

## 1.1. Background

Sub-Saharan Africa has still high mortality and fertility compared to other regions of the world. More specifically, it is the only major region of the developing world that has not yet undergone a general decline in fertility, except in parts of Southern Africa (Cohen 1998; Moultrie and Timæus 2003; Mturi and Joshua 2011; Bongaarts and Casterline 2012). Mortality has been declining slowly in the region. Even, it has either ceased to decline or increased in some countries in the region (Timaeus 1999; Garenne and Gakusi 2006). Of particular interest to the current study is the under-five mortality rate (U5MR) in the region. From the demographic transition theory, child mortality decline is one of the drivers of fertility decline. Hence, efforts to reduce U5MR are not only useful to improve child and maternal health but also essential to promote fertility decline. In fact, U5MR is used as an indicator of wellbeing of a population, which makes it as one of the barometers to measure development.

Progress to reduce U5MR in the region is slow relative to the rate of decline required to achieve the target set by Millennium Development Goals 4 (Murray, Laakso, Shibuya, *et al.* 2007; UN-IGME 2013). The slow socioeconomic development, political instability and the impact of HIV in the region are thought to contribute to the regions' slow mortality decline (Timaeus 1999; Adetunji 2000; Garenne and Gakusi 2006). Substantial part of the region's population do not have access to safe drinking water and improved sanitation (UNECA, AU, AfDB and UNDP 2013).These and other poor living conditions have a bearing on the quality of the environment where children are raised. Studies indicate that better household environmental conditions are crucial for child survival (Rutstein 2000; Woldemicael 2000; Mesike and Mojekwu 2012). However, such studies relating environmental health hazards with U5MR are rare in sub-Saharan Africa. Using 12 countries' recent DHS data sets in the region, this study aims to close the knowledge gap in the subject. The study places especial emphasis to potential interaction effects between household environmental health hazards and the age of the child.

## 1.2. Statement of the problem and significance of the study

It is highlighted in the previous section that improving child health and mortality is one of the priorities of development agenda in developing countries stated under MDG4. In this regard, developing nations are making concerted efforts to achieve their goals. However, countries in sub-Saharan Africa have still high levels of child mortality and they are also making slow progress for its reduction (Murray, Laakso, Shibuya*, et al.* 2007; UN-IGME 2013). The level of U5MR in the region is 98 deaths per 1000 live births, which is more than 15 times the corresponding rate for the developed world (UN-IGME 2013).

Studies indicate that several factors play to affect child health and survival. Hence, the prospect for reducing child mortality depends on understanding such issues among other things. Among these factors, the environment where children live plays a role in child health and survival (Mosley and Chen 1984). While several researchers explore the effect of various socioeconomic and demographic factors on child health and survival in the region, such studies pay little attention to the household environmental conditions (Griffiths, Madise, Whitworth and Matthews 2004; Mogford 2004; Bawah and Zuberi 2005; Harttgen and Misselhorn 2006; Omariba and Boyle 2007; Boco 2010). Furthermore, the few existing studies on the subject in the region pay very little attention to understand when in the course of the child's development the environment does have a significant effect on its health and survival. In addition to this, such studies do rarely account the effect of the community context and the potential clustering of health outcomes in certain communities.

In this study, I argue that understanding the effect of the household environmental conditions on under-five mortality and its potential differential effect on the risk of mortality during the course of the child's development helps to improve policies and interventions. In particular, the findings can help sharpen interventions and programmes working on environmental health.

### 1.3. Objectives of the study

The general objective of this study is to assess the effect of household environmental health hazards on under-five mortality in sub-Saharan Africa. This goal is translated into three specific objectives: i) measuring the effect of environmental health hazards on the risk of death before age five in the region; ii) exploring the potential interaction effects between environmental health hazards and the age of the child and iii) comparing the effects of environmental health hazards on the risk of under-five mortality between countries included in the study.

### 1.4. Thesis organization

This thesis consists five chapters each having several sections. The first chapter introduces the background, the problem and objectives of the study. In the second chapter, I review the related literature that covers topics on the current state of under-five mortality in the region; the essence of environmental health hazards; framework to study child health and survival; and empirical evidence on the determinants of child health and survival. At the end of this chapter, I propose tentative conceptual framework for the study. The third chapter describes data and method of analysis, especially the multilevel discrete-time hazard model. The findings of the study are presented in the fourth chapter. While the first two sections of this chapter cover descriptive statistics, the last section is dedicated to results related to modelling. In chapter 5, I discuss the result in relation with previous studies and also present the limitations of the study. Finally, I end the study with conclusion in the same chapter.

# 2. LITERATURE REVIEW

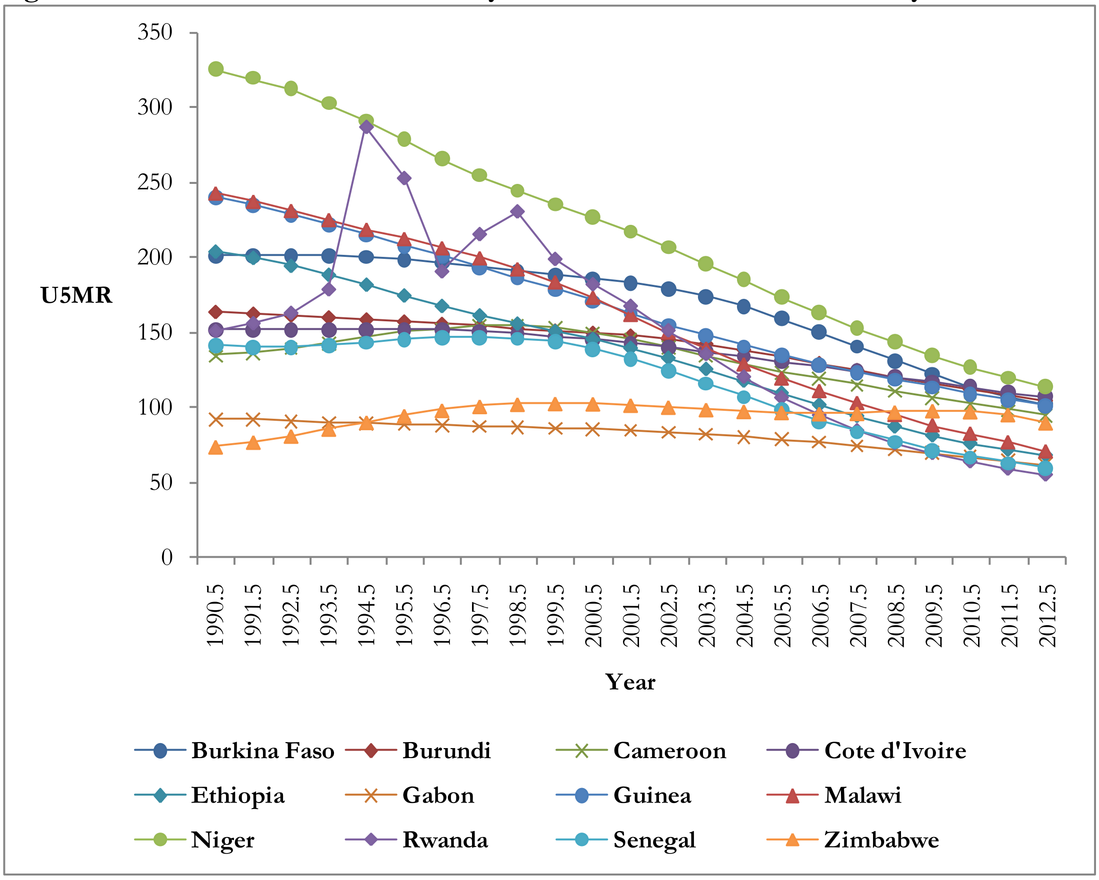
In this chapter, I present a critical review of the literature on child health and mortality. Child mortality in this context does not mean strictly mortality between age one and five; rather, it is in the wider context of under-five mortality, which includes infant deaths in addition to mortality between age one and five. Whenever necessary, distinction between infant and childhood mortality is made clear in the review. The chapter is organized based on four themes, which are relevant to the current study: the state of child health and mortality in sub-Saharan Africa; the link between environmental health hazards and child health and mortality; evidence on other major covariates of child mortality; conceptual framework and methodological issues in the study of child survival.

## 2.1. Under-five mortality in sub-Saharan Africa

U5MR is defined as the probability of dying between birth and age five, which is usually expressed per 1000 live births. It is commonly used as a measure of child health and wellbeing in a society. As it is going to be clear in subsequent sections, U5MR captures the outcomes of several dimensions such as the health care, nutrition, sanitation and safe drinking water, economic development etc. Indeed, it is one of the development indicators that are used to set the Millennium Development Goals (MDGs). In particular, MDG4 states a reduction of U5MR from its 1990 level by two-thirds in 2015 (Claeson and Folger 2008). Many nations (including those in sub-Saharan Africa) are making concerted efforts to realize the envisaged goal (OMS, UNICEF, UNFPA and Mondiale 2010). For instance, similar endeavours help Niger to reduce its high level of U5MR from 226 deaths per 1000 live births in 1998 to 128 deaths in 2009 with a 5·1 per cent annual rate of decline, which is more than that is expected to achieve MDG4 (Amouzou, Habi and Bensaïd 2012).

However, in general, sub-Saharan Africa is making slow progress towards the anticipated U5MR reduction in contrast to the rest of the developing world (Murray, Laakso, Shibuya*, et al.* 2007; UN-IGME 2013). Globally, U5MR has declined from 90 deaths per 1000 live births in 1990 to 48 deaths per 1000 live births in 2012. In addition, during the same period, the global under-five deaths declined from 12.6 million to 6.6 million. By contrast, the level of U5MR in sub-Saharan Africa declined from 177 to 98 deaths per 1000 live births for the same period. This rate is more than 15 times the figure for the developed world (UN-IGME 2013). Moreover, the pace of decline in U5MR is not sufficient to achieve MDG4 in many countries in the region (Murray, Laakso, Shibuya, *et al.* 2007; UN-IGME 2013). With the current level and pace of decline, the region remains as one of those with the highest level of under-five deaths (UN-IGME 2013).

**Figure 2.1.Trends in under-five mortality in countries included in the study**




Source: UN-IGME, 2013

In addition to the high level of U5MR, disparities in U5MR are also present within countries (Boco 2010) as well as among countries and sub-regions (UNECA, AU, AfDB and UNDP 2013). Several countries in West and Central Africa have higher levels of mortality compared to countries in Southern and East Africa. In particular, U5MR in the Central African sub-region is the highest in the region, with 139 deaths of children per 1,000 live births in 2011. Moreover, the pace of decline in under-five mortality for the same sub-region is the lowest in Africa (UNECA, AU, AfDB and UNDP 2013). Figure 2.1 shows trends in U5MR in countries included in the current study. The trend suggests that U5MR is declining in most of these countries, except in Zimbabwe and Gabon where the trend is relatively flat between the years 1990 and 2012. The trend also reveals that the disparity in U5MR among these countries is closing over the years even if persistent disparities remain.

Several infectious diseases (including diarrhoea, malaria and HIV) account for about 41 per cent of deaths of under-five children in Africa (UNECA, AU, AfDB and UNDP 2013). In particular, diarrhoea and intestinal parasites which are causes of death and ill-health for a number of children every year are closely associated with inadequacies in the provision of water and sanitation (Bartlett 2005). These and similar living conditions partly determine the environmental situation that may influence the health and survival of children. In fact, the importance of a broad range of environmental issues is the theme of the Millennium Development Goals 7 (MDG7), which is about ensuring sustainable environment. Tracking the achievement of MDG7 is based on several indicators, including access to safe drinking water and sanitation.

While the global target for providing safe drinking water is met, sub-Saharan Africa has not yet achieved the target for providing safe drinking water. In particular, disparities in coverage of safe drinking water exist among regions of the world. Globally, 89 per cent of the population had access to safe drinking water in 2010 (UNICEF and WHO 2012). By contrast, the corresponding figure in sub-Saharan Africa is 61 per cent for the same year (UNICEF and WHO 2012). Specifically, 13 per cent of the population in the region use surface water and another 26 per cent use other unimproved sources in 2010 (UNICEF and WHO 2012). In addition, much of sub-Saharan Africa is unlikely to meet the improved sanitation facility target. In the year 2010, 25 per cent of the population in the region defecate in open areas while another 26 per cent use unimproved sanitation facility (UNICEF and WHO 2012; UNECA, AU, AfDB and UNDP 2013). Differences in child health and mortality due to disparities in the quality of the living environment are inevitable under the current state of performance in environmental outcomes in the region.

Previous studies affirm the role of environmental factors on child health and mortality (Trussell and Hammerslough 1983; Timaeus and Lush 1995; Woldemicael 2000). A study in West Africa shows the importance of population density, climate and disease environment for understanding variation in infant and child mortality (Balk, Pullum, Storeygard, *et al.* 2004). A similar study by Root (1999) also affirms the role of disease environment in understanding spatial variation in U5MR in the region. In addition, a study by Fayehun (2010) shows that survival chances among under-five children who live in non-hazardous household environment is higher in high mortality countries in the region. A study in Eritrea also shows that improved household water and sanitation enhance child survival (Woldemicael 2000). However, in general, these studies on the impact of the household environment on U5MR lack completeness in the household conditions used to determine the quality of the environment and give little attention in the potential differences in its impact according to the age of the child. Moreover, they give little importance to community contexts and ignore the tendency that deaths might cluster in certain communities.

Even though the importance of community contexts to child health and survival is acknowledged, empirical studies on community contexts are relatively rare in sub-Saharan Africa. Moreover, many of the existing studies place undue emphasis on particular countries. For instance, the effects of the various aspects of the community on child mortality in Nigeria are the subjects of many studies (Antai and Antai 2008; Antai and Moradi 2010; Antai, Wedre´n, Bellocco and Moradi 2010; Antai 2011; Adedini 2013; Adedini, Odimegwu, Imasiku*, et al.* 2014 ). On the other hand, using DHS data sets from 22 sub-Saharan African countries, Omariba and Boyle (2007) examine community contexts with emphasis on polygyny. Other similar studies with a general focus on community effects and cross-national comparison include a study of U5MR by Boco (2010) and a study of child mortality and nutrition by Harttgen and Misselhorn (2006). In general, these studies give little or no importance to the household environment.

### 2.2. Environmental health hazards

Ensuring a sustainable environment is related to several issues, including release of toxic chemicals and gases, water and sanitation. Thus, the defining elements of environmental contamination or health hazards might reflect the status of these and other indicators in the environment. This study focuses on some aspects of household environmental health hazards on under-five mortality related to household building materials, cooking fuel, water and sanitation. The conditions of the above, among others, determine the availability of health hazards or environmental contaminants (Mosley and Chen 1984; Pongou, Ezzati and Salomon 2006; Fayehun 2010). While the importance of broad environmental issues in child health and mortality is highlighted in the previous section, the following paragraphs present a review of further detailed evidence with emphasis on the effect of household environmental conditions on child health and mortality.

By using meta analysis of the empirical evidence from several studies, Esrey, Feachem and Hughes (1985) indicate that improvements in water and excreta disposal are associated with substantial reduction in child mortality. They note that improvements in the quantity of water or sanitation have a greater effect than the quality of water. This is perhaps because the quantity and availability of water might influence personal hygiene and household cleanliness, which can reduce faecal contamination. Another study using data from various sources by Gakidou, Oza, Fuertes*, et al.* (2007) assesses the effects of environmental and nutritional interventions on child mortality in developing regions, including sub-Saharan Africa. It reveals that a substantial reduction in child mortality could be achieved through improvements in water, sanitation and household fuels. Furthermore, using DHS data from six Francophone countries in sub-Saharan Africa, Van de Poel, O'Donnell and Van Doorslaer (2009) attribute the relative rural disadvantage in infant mortality partly to environmental factors. In particular, their study has found a negative relationship between infant mortality and safe source of drinking water in both rural and urban areas and higher mortality risk for infants living in households with unfinished floor in urban areas. A similar study using DHS data in Nigeria also reveals that improved household conditions (safe water, proper sanitation, and less pollutant cooking fuel) enhance child survival (Uthman 2007). The study by Mesike and Mojekwu (2012) for the same country also strengthens the above conclusion. Specifically, it reveals that child mortality is low among households with better building materials (roofing and flooring materials), with sanitation facilities and those who use non-pollutant cooking fuel. Similar results are also found in other parts of the world. For instance, a study by Martin, Trussell, Salvail and Shah (1983) in three Asian countries indicates that infant and child mortality are lower among households having electricity and better sanitation.

Apart from the effect of environmental conditions on child mortality, their effects on child health are also affirmed by several studies (Esrey, Feachem and Hughes 1985; Esrey, Potash, Roberts and Shiff 1991; Jinadu, Olusi , Agun and Fabiyi 1991; Timaeus and Lush 1995). More specifically, a number of such studies documenting similar results are conducted in countries of sub-Saharan Africa. For instance, a study in Ghana and Nigeria by Ahiadeke (2000) shows higher risk of diarrhoeal diseases among children in households with poor sanitation and unimproved water sources. A similar study in Zimbabwe indicates that children from households with access to toilet are less likely to be stunted (Mbuya, Chideme, Chasekwa and Mishra 2010). Using DHS data sets from

Cameroon, Pongou, Ezzati and Salomon (2006) also examine the effects of environmental factors on child nutritional status. Their findings indicate that improved household conditions (i.e. improved water, sanitation and cooking fuel) have positive effect on child nutritional status.

Furthermore, a number of studies have documented the health effects of using biomass fuel for cooking in developing countries. For instance, using critical review of researches on the subject, Smith, Samet, Romieu and Bruce (2000) study the influence of indoor air pollution from biomass fuel in less developed countries. Their study indicates that studies on the subject find consistently higher risk of Acute Respiratory Infections (ARI) and pneumonia among children who are exposed. Furthermore, they note that this association is also found in a number of studies that control for potential confounders. Similar meta analyses also indicate that exposure to unprocessed solid fuel or indoor air pollution have increased risk of pneumonia (Dherani, Pope, Mascarenhas, *et al.* 2008) and lower respiratory tract infections (Fuentes-Leonarte, Ballester and Ten´ıas 2009). Besides, a study using DHS data from 29 developing countries by Kyu, Georgiades and Boyle (2010) shows an association between mild anaemia and exposure to biomass fuel at home among under-five children.

Apart from the above studies on wider geographical areas, there are a number of similar studies that examine the health effects of indoor air pollution due to using biomass fuel for cooking in a number of countries in sub-Saharan Africa. For instance, a study using longitudinal data and field observations among subjects that includes infants and children in Kenya shows that exposure to pollutants (particulates smaller than 10 μm in diameter) due to biomass combustion is associated to ARI (Ezzati and Kammen 2001). Another study in Zimbabwe by Mishra (2003) also reveals that children from households who use biomass fuel for cooking are more than two times as likely to suffer from ARI compared to children from households who use LPG or electricity net of several potential confounders. A similar study among under-five children in Abijan by Sackou, Oga, Tanoh, *et al.* (2014) also indicates an association between respiratory symptoms and solid fuel burning at home. On the other hand, using Swaziland's DHS (2006/2007) data, Machisa, Wichmann and Nyasulu (2013) find no significant association between using biomass fuel for cooking and stunting among children of age 6-36 months. In general, similar findings are also documented in other developing countries. For example, a study in Guatemala by Boy, Bruce and Delgado (2002) indicates that children whose mothers use wood in open fires for cooking have low birth weight after controlling for the effects of maternal, social and economic factors. A similar study using survey data from India by Mishra and Retherford (2006) indicates a significant effect of using biomass fuel for cooking on anaemia and stunting among children after adjusting for the effects of a number of potential confounders.

## 2.3. Other covariates

In addition to the influence of environmental factors on child health and survival, the empirical evidence on other covariates is immense. Research on this topic comprises analyses of the effects of numerous socioeconomic and bio-demographic factors at the macro and micro level. Moreover, relatively recent works on the subject tend to combine individual, household and neighbourhood units. The literature shows that the knowledge base on the covariates of child survival is mainly from surveys and censuses. In particular, World Fertility Surveys (WFS) and Demographic and Health Surveys (DHS) are clearly seen to be vital sources of information for the study of child survival in developing countries. Given the abundant knowledge on the subject, a systematic review of the literature based on the nature of the factors and the observational unit which they characterize is helpful to understand clearly the covariates of child health and survival. To this end, we attempt to review separately the literature of the effects of community-level characteristics, household and individual-level covariates.

### 2.3.1. Household and individual-level variables

#### 2.3.1.1. Bio-demographic factors

Many studies have shown the influence of maternal factors, including birth-interval, birth-order and maternal age at birth on child mortality (Manda 1998; Omariba, Beaujot and Rajulton 2007). In particular, short birth-interval is usually associated with high risk of death among under-five children. A study in Bangladesh and the Philippines by Miller, Trussell, Pebley and Vaughan (1992) shows high mortality rate for births within short period from the previous child after controlling for the effects of other potential covariates. Using longitudinal data in Bangladesh, Koenig, Phillips, Campbell and D'Souza (1990) find high neonatal mortality rate for births with short birth interval from previous child. They attribute this effect to physiological effects on the mother due to closely spaced pregnancies.

In addition to the influence of birth-interval on child mortality, a study using DHS data sets from 13 African countries by Van Malderen, Van Oyen and Speybroeck (2013) reveals a substantial contribution of birth-order, among other factors, towards overall inequality in under-five mortality. The study by Boco (2010) in the same region also shows high risk of death among under-five children of high birth-order and short birth-interval. Competition of siblings and maternal depletion are commonly suggested reasons for the relatively high risk of death among children of high birth-order and short birth-interval (Koenig, Phillips, Campbell and D'Souza 1990; Miller, Trussell, Pebley and Vaughan 1992; Zenger 1993; Bolstad and Manda 2001).

The survival chances of children of young and old mothers are less compared to children of mothers who are neither too old nor too young (Trussell and Hammerslough 1983; Sastry 1996; Bolstad and Manda 2001). Some researchers suggest that the non-linear effect of maternal age on child mortality can be attributed partly to lack of experience in child care among young mothers and due to maternal depletion among old mothers.

Apart from the effect of the above demographic factors, mortality differential by sex is a well-established fact in demography in which males have higher mortality rate than females in cultural settings where there is less gender discrimination. Many empirical studies confirm this pattern (Hill and Upchurch 1995; Sastry 1996; Boco 2010). On the contrary, female disadvantage in child mortality is quite common in the Indian sub-continent (Das Gupta 1990; Singh, Hazra and Ram 2007).

Finally, one important factor which is stressed by several studies to understand clearly disparities in child mortality in sub-Saharan Africa and especially in Southern Africa is the effect of HIV/AIDS. Several studies use the adult HIV prevalence to assess the effect of HIV/AIDS on infant/child morality. In particular, a method which is developed by Zaba, Marston and Floyd (2003) uses the adult HIV prevalence rate among other things to estimate child mortality levels attributable to HIV. Adetunji (2000) also looks at the link between adult HIV prevalence and under-five mortality trends in developing countries. His study indicates that the effect of HIV is noticeable in countries where the prevalence is high. The above result is also reinforced by two similar studies, which show a positive relationship between adult HIV prevalence and child mortality in sub-Saharan Africa (Mogford 2004) and in many countries worldwide (Gakidou, Cowling, Lozano and Murray 2010).

#### 2.3.1.2. Socioeconomic factors

A commonly used proxy for household income in survey based studies is the household wealth index constructed based on availability of various items in the household. Various studies indicate a negative relationship between the household wealth index and child mortality in sub-Saharan African countries (Van de Poel, O'Donnell and Van Doorslaer 2009; Van Malderen, Van Oyen and Speybroeck 2013; Adedini, Odimegwu, Imasiku*, et al.* 2014 ). Using census data, Bawah and Zuberi (2005) have also found an inverse relationship between childhood mortality and a measure of socioeconomic index in Southern Africa.

Of the studies on the effect of socioeconomic factors on child health and survival, the effect of maternal education on child mortality is one of the most frequent topics of discussion in the literature. The negative relationship between maternal education and child mortality is almost a universal fact that is founded on many empirical researches all over the globe (Martin, Trussell, Salvail and Shah 1983; Buor 2003; Mogford 2004; Gakidou, Cowling, Lozano and Murray 2010; Pamuk, Fuchs and Lutz 2011; Song and Burgard 2011). However, scholars debate on the mechanisms through which a mother's schooling positively influences child health and survival. One of the most important contributions in the debate for pathways for the effect of maternal education is made by Caldwell (1979). It is based on his study in South Western Nigeria. He argues that education is very influential in child mortality on its own. He provides three possible explanations for how maternal education can bring lower child mortality. First, change in perspectives among educated women from a fatalistic view of death towards an understanding that child health and mortality can be controlled in some ways. Second, educated mothers are confident enough to manipulate and exploit the modern world, including health facilities and health personnel. Third, change in family relationship which gives autonomy for educated women that might be beneficial for their children's health and survival.

Further, supporting evidence indicates that education enables mothers to use preventive and curative medical care (including ORS, immunization, prenatal care, vaccination, assistance of health professionals during delivery); enhances their knowledge on health; facilitates the reception of health message; improves communication skills that facilitates interaction with the health system; and improves child care skills and domestic treatment of illness (Das Gupta 1990; Hobcraft 1993; Caldwell 1994; Jain 1994; Vikram, Vanneman and Desai 2012). On the other hand, Desai and Alva (1998) argue that maternal education is a proxy for socioeconomic status of the households and the characteristics of residential areas in which educated mothers are associated with. Further, they suggest that the link between maternal education and child health is either weak or spurious. A similar argument by Kaufmann and Cleland (1994) treats maternal education as a proxy for social factors and as a means to enhance existing personal qualities, which are favourable for childcare.

In addition to the influence of the above covariates, studies indicate that access and use of medical services improve child health and survival (Manda 1998; Harttgen and Misselhorn 2006). In particular, the risk of under-five mortality is less among children whose births are attended by skilled professionals than those whose births are attended by non-professionals (Manda 1998; Boco 2010). Similarly, the risk of under-five mortality is lower among children whose births took place in hospital (Bolstad and Manda 2001). A study by Rutstein (2000) also reveals that maternal care services ( including skilled birth attendance, prenatal care and delivery at a health facility) lower the risk of under-five mortality. The same study also finds vaccination and medical treatment to illness among other factors play a role in child mortality decline in developing countries during the 1990s. Other related factors that may directly or indirectly affect child health and survival through skilled birth attendance and place of delivery include distance to health facilities, quality and availability of antenatal services. In particular, using DHS data from four African countries, Adjiwanou and LeGrand (2013) find that use of skilled birth attendance improves with the quality of antenatal care after correcting for endogeneity bias. Similar studies also show that distance from a health facility and level of care are associated with place of delivery. In particular, the likelihood of delivering at a health facility increases as level of care increases and the distance to the closest facility decreases (Gabrysch and Campbell 2009; Gabrysch, Cousens, Cox and Campbell 2011). Thaddeus and Maine (1994) also identify distance, cost, and quality of care among others as determinants of care seeking for obstetric treatment.

Finally, several studies have tried to explore the influence of, religion, ethnicity, migration status and others. Using Nigerian DHS (2003), Antai and Antai (2008) find significant association between under-five mortality and religion. In another study, one of these researchers, Antai (2011) finds a significant association between under-five mortality and ethnicity in the same country. In a similar study in Ghana, Gyimah (2002) argues that ethnic inequalities in infant mortality is mainly due to socio-economic differences. Using Nigerian DHS (2003), Antai, Wedre´n, Bellocco and Moradi (2010) find that children of rural non-migrant mothers have significantly lower risk of under-five mortality than children of rural-urban migrant mothers.

### 2.3.2. Community level covariates

Understanding how community and individual effects work to influence health outcome enhances inference about community effects and is also useful for policy intervention (Diez-Roux 2001). This involves several issues, including what constitutes community or neighbourhood. Huie (2001) and Diez-Roux (2001) notice that defining community is a challenging, complex and debatable issue. However, both scholars argue that it involves, in general, social and spatial dimensions and its definition depends on hypotheses and characteristics of the community in the study. They notice that administrative units, census tracts and blocks are usually used as proxies to neighbourhood. In short, the above discussion reflects that the definition of community is no less important as Kawachi and Subramanian (2007: 3) claim "identifying 'true' neighbourhood effects requires identifying 'true' neighbourhoods".

The study of community contexts also involves measurement issues. Measuring community characteristics are mainly accomplished in two ways. One of the methods involves aggregating individual or household characteristics within the given community. This approach is commonly used in DHS based studies to understand differences in child health and mortality among communities. These characteristics include level of poverty in a community, which is usually measured as the proportion of poor households in the community; community-level of maternal education which is commonly measured as the proportion of women who have a certain level of education or higher; and access to health in the community which is measured by various proxies, including the proportion of women who are assisted by health professional during delivery and the proportion of children who are immunized in the community (Antai and Antai 2008; Boco 2010; Adedini, Odimegwu, Imasiku*, et al.* 2014 ). The second type of community characteristics include variables related to the geographical location of the community. These include the type of residence (rural or urban), province (or administrative region), etc.

A study by Kravdal (2004) indicates that the level of maternal education in a community has a significant relationship with child mortality beyond the effect of the mother's own education in India. A similar effect of community-level maternal education on under-five mortality is also found by Boco (2010) in his study in sub-Saharan Africa. On the other hand, based on his study in Brazil, Sastry (1996) argues that the quality of education has significant effect on child mortality but not the coverage of primary schooling. In particular, his study indicates that child mortality is lower in communities with better schools. He suggests that community-level education affects child mortality through its influence on norms and attitudes in child care and reproductive behaviour.

Another aspect of the community that is used to explain variation in child mortality among communities is the level of poverty in the community. Studies show that mortality among children living in poor communities is relatively high in Kenya and Nigeria (Boco 2010; Adedini, Odimegwu, Imasiku, *et al.* 2014 ). Furthermore, national economic indicators (including GDP and GNP per capita) are used by numerous studies to assess the effect of income on child health and mortality. A global study at the national level by Gakidou, Cowling, Lozano and Murray (2010) indicates that increase in GDP per capita results in a significant reduction in child mortality rate. A similar study at the national level shows that increase in foreign debt is related to excess U5MR in sub-Saharan Africa (Mogford 2004).

Other important aspects of the community that are commonly used to understand variation in child health outcome and mortality are indicators of access to health care. Using Nigerian DHS (2008), Adedini, Odimegwu, Imasiku, *et al.* (2014 ) find that lower infant mortality is found in communities where the proportion of hospital delivery is higher. The study by Boco (2010) also concludes that the health care context plays a major role in child survival. Specifically, it reveals that children living in communities where a high proportion of children are immunized have a low mortality risk. Although the health service context is important, it might also be influenced by the gender norms in a community. Specifically, Adjiwanou and LeGrand (2014) find that in communities where violence against women is tolerated, women are less likely to deliver with professional assistance and use other maternal health services. Other community level factors that are addressed in related studies include the effect of ethnic diversity, availability of infrastructures, the neighbourhood environment, and place of residence (Sastry 1996; Boco 2010; Adedini, Odimegwu, Imasiku, *et al.* 2014 ).

## 2.4. Conceptual framework and other methodological issues

Though identifying the covariates of child health and survival is important, it is not sufficient for policy implication unless it is complemented by a theoretical framework, which can describe the link among covariates (Mosley and Chen 1984). Thus, it is helpful to see some conceptual models due to their use in a number of ways. First, they are helpful to identify potential predictors and provide the means to quantify them (Mosley and Chen 1984). In addition, if they are used as guides in the modelling process, they result in useful information (Masuy-Stroobant 2001). Given the above uses of conceptual frameworks, the following sub-sections are dedicated to a brief review of the commonly used framework by Mosley and Chen's (1984) and other related concepts.

### 2.4.1. Mosley and Chen's framework (1984)

The commonly used framework for the study of child health and mortality is developed by Mosley and Chen (1984). The development of this framework is based on the pit falls in the social and medical sciences approaches that they identify. In particular, they note that social science approaches focus on the relationship between socioeconomic variables and child mortality while ignoring the channels (proximate determinants) through which socioeconomic variables work to influence child survival. On the other hand, medical science studies give emphasis to the biological process of diseases. Thus, one of the strengths of Mosley and Chen's approach is that it is build up on by improving these limitations. In short, their framework integrates social and medical science approaches and, therefore, includes biological as well as socioeconomic variables.

Five key assumptions are central to their approach. First, they claim that the survival rate past age five under optimal condition is 97 per cent. Second, variations of survival rate from the corresponding rate under optimal condition can be explained by socioeconomic, biological and environmental factors. Third, the prevalence of diseases and malnutrition are manifestations of the workings of proximate determinants (i.e. these variables have a direct influence on child health outcome). Fourth, socio-economic variables affect child health outcome via proximate predictors. Fifth, child health outcomes are the results of numerous disease processes.

Besides, they argue that the identification of numerous proximate determinants that they classify into five categories is central to their approach. One of these categories is maternal factors, which include age, parity, and birth interval. The other four categories are environmental contamination, nutrient deficiency, injury and personal illness control. They give a detailed explanation of how these proximate factors influence child health and mortality. Of particular interest to this research are the mechanisms for environmental contamination. In short, they state that environmental contamination forms the medium through which air-, water-, and soil-borne diseases, including respiratory, intestinal and diarrhoea are spread.

In addition, by classifying socioeconomic factors into individual, household and community-level variables, their approach offers potential path ways for the influence of these factors on child health and mortality. One of their arguments is that fathers' and other non-childbearing household members' attributes (including education and occupation) influence child health and mortality through income effect via proximate determinants. By contrast, they argue that mothers' education might influence her health practice, which might influence directly their children's health and survival. In addition, they mention a list of items, including food, water, and housing that the effect of household income works through to influence child survival. Finally, they attribute community effects to ecology, political economy and the health system.

### 2.4.2. Mechanisms for community effects

An elaborate mechanism for community effects on individual-level health outcome and behaviour is discussed by Galster (2010). He suggests numerous pathways grouped into broad categories: social interactive, environmental, geographical and institutional. His approach integrates sociological and epidemiological perspectives. The first category involves social processes in the community, which include social contagion, collective socialization, social networks, social cohesion and control, relative deprivation, and parental mediation. The processes in this category operate through interaction and information exchange among members in the community to influence behaviour, norms, etc. The second category is due to the community's characteristics that influence health outcome without affecting individuals' behaviour. This includes the conditions of public infrastructure; exposure to violence; and exposure to toxic pollutants in air, water and soil. The third category refers to the geographical location of the community, which is characterized by accessibility and transportation networks that influence job opportunities, personal developments and education. The last category refers to actions of institutional and private actors, which might affect health through stigmatization of residents of the community; accessibility to local institutional resources (schools, clinics etc); and the role of local market actors to encourage or discourage certain behaviours of residents in the community.

Diez-Roux (2001) argues that community effects work, in general, through individuals where individual-level variables are conceptualized as either confounders or mediators in the pathway. Moreover, she adds that neighbourhood effects on health outcomes should be seen from broader perspective since variation in contextual effects are a result of macro-structural factors, including political decisions, public and institutional policies.

### 2.4.3. Unobserved frailty

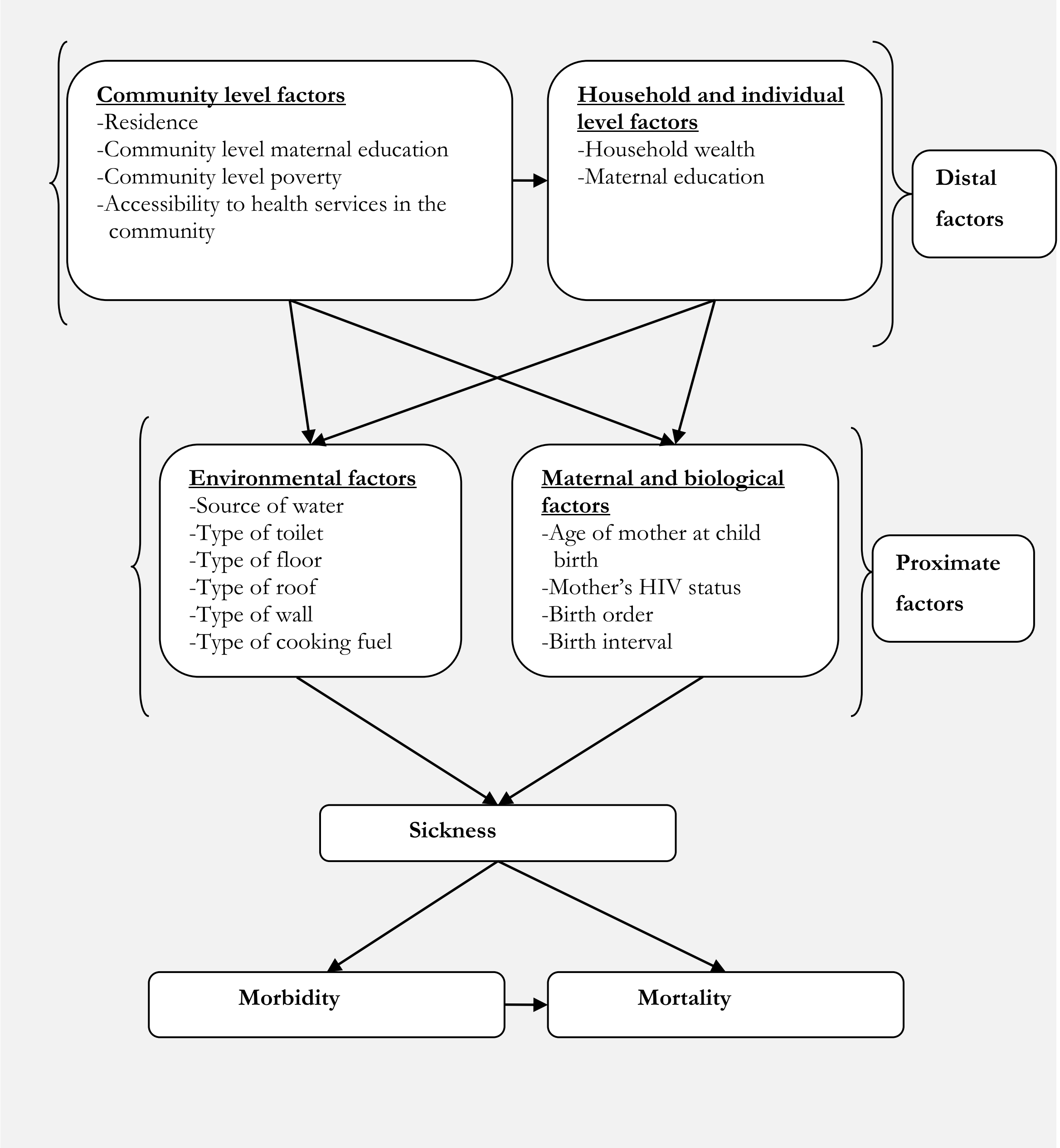
In his study of child mortality in Northeast Brazil, Sastry (1997) discusses a framework for interpreting sources of unobserved frailty. In survival studies, the term frailty represents an individual's susceptibility to the risk of death. In particular, the author classifies sources of unobserved frailties in the study of child survival as genetic, behavioural, and environmental that might operate at several observational units including the individual, the family and the community. Moreover, he remarks that attaching a meaning to unobserved frailties depends on those measured factors, which are included in a model.

According to his framework, unobserved frailties at the family-level include shared genetics among siblings, parental competence, household environment etc. Moreover, he notes that unmeasured behavioural factors can be reflected at the community-level because people living in the same community are exposed to similar cultural influences. Besides, he contends that unmeasured environmental factors tend to operate more at the community-level than at the family-level because children in the same community are exposed to similar physical and social environment, and diseases.

## 2.5. A tentative framework for the study

In this section, I propose a tentative conceptual framework adapted from Mosley and Chen's (1984) framework and using inputs from the literature that is reviewed so far. Figure 2.2 depicts the proposed mechanisms, which links the various factors and the outcome variable (child survival status before age 5). The framework implies that community-level factors influence child survival through household or individual-level covariates (Diez-Roux 2001; Galster 2010). Socioeconomic factors (including maternal education and household wealth) influence child mortality through environmental, maternal and biological factors (Mosley and Chen 1984).

**Figure 2.2. Conceptual framework adapted from Mosley and Chen (1984)**



# 3. DATA AND METHODS

## 3.1. Data and coverage

The study uses recent DHS data sets from 12 sub-Saharan African countries. The DHS collect information from respondents on fertility, family planning behaviour, socioeconomic characteristics of respondents and others. Respondents for DHS surveys are a nationally representative multi-stage sample of women and men in the reproductive age groups 15-49 and 15-59, respectively. The surveys are intended to provide estimates of key population and health indicators, including fertility and mortality rates for surveyed countries. Table 3.1 and the map under Figure 3.1 show the selected countries for the current study. The population of these countries is roughly 26[1] per cent of the sub-Saharan African region's 926 million peoples in 2013 (PRB 2013 ). The selection of these countries is based on the availability of recent DHS data sets (roughly those within the last five years), which are also comparable in terms of measurement. Fortunately, the selection covers countries from all sub-regions. However, Mozambique and Tanzania which conducted similar surveys in recent periods are excluded due to unavailability of some variables for the study. The study uses information from all children who were born within five years prior to the survey date.

**Table 3.1. Countries included in the study**

| Country | Survey | Phase |
|---|---|---|
| **Burkina Faso** | 2010 DHS | DHS-VI |
| **Burundi** | 2010 DHS | DHS-VI |
| **Cameroon** | 2011 DHS | DHS-VI |
| **Cote d'Ivoire** | 2011-12 DHS | DHS-VI |
| **Ethiopia** | 2011 DHS | DHS-VI |
| **Gabon** | 2012 DHS | DHS-VI |
| **Guinea** | 2012 DHS | DHS-VI |
| **Malawi** | 2010 DHS | DHS-VI |
| **Niger** | 2012 DHS | DHS-VI |
| **Rwanda** | 2010 DHS | DHS-VI |
| **Senegal** | 2010-11 DHS | DHS-VI |
| **Zimbabwe** | 2010-11 DHS | DHS-VI |

[1] The percentage is the researchers own calculation from PRB, 2013 estimates

**Figure 3.1. A map of countries included in the study**


## 3.2. Variables included in the study

The response variable is constructed for births in the last five years from the interview date of each survey from the birth history data. In particular, the response represents the number of months from birth until death for those who died or the length of time from birth to the interview date for those alive during the interview. Further, this time is transformed into a discrete scale of five intervals: 0, 1-5, 6-11, 12-23, and 24-59 months (Sastry 1996; Sastry 1997; Boco 2010). Several covariates that are identified from the literature are included in the study. They cover socioeconomic and proximate factors at the individual, household and community level. Their specific definitions and the scale of measurement are given in Table 3.2. In this study, the primary sampling units, which are usually census enumeration areas (clusters) in DHS, are used to approximate communities.

**Table 3.2. Definitions of covariates**

| Variable name | Definition |
|---|---|
| **Household environmental health hazards** | A composite index measuring the level of health hazards in the household environment which is measured in a continuous scale |
| **Sex** | Sex of the child with categories male and female. |
| **Birth order and interval**[2] | The order of a birth and the time since last birth to the birth date of the index child with categories First; Second and >=24 months; Second and < 24 months; >=3 and >=24 months; >=3 and < 24 months |
| **Mother's age at child's birth** | The age of the mother at the birth of the child in years with categories <20, 20–34, and >34 years |
| **HIV** | Blood test result for HIV of the mother with categories Negative, Positive and Not tested |
| **Mother's education** | Highest level of education of the mother with categories No education, Primary, and Secondary or higher |
| **Household wealth status**[3] | Wealth status of the household with categories Poor, Middle, and Rich |
| **Community level covariates** | |
| **Residence** | Place of residence with categories Urban and Rural |
| **Community level of women's education** | Proportion of women with secondary or higher education in the community |
| **Community level of poverty** | Proportion of poor households in the community |
| **Community level of health service accessibility** | A composite index measuring health service accessibility in the community measured in a continuous scale |

[2]Birth order and time in months since the previous birth are combined to produce a single variable because birth interval is not defined for first births.

[3] The first two wealth quintiles are grouped as poor; the third quintile is labeled as medium; and the last two quintiles are labeled as rich.

### 3.3. Principal component analysis

When several indicators for measuring a certain quantity exit, a measure of composite index usually simplifies comparison. In social science, composite indices are constructed based on aggregation of several variables to measure socioeconomic status and wealth. Similar methods for constructing such indices are also used in various fields. Some of the methods involve simple weighted average and weighted geometric mean. A popular method for constructing a composite index is the principal component analysis. This technique is widely used to construct asset, socioeconomic, health service and environmental indices from several indicators (Bawah and Zuberi 2005; Harttgen and Misselhorn 2006; Khatun 2009). One of the advantages of using this method is that the weights for aggregating the variables are determined based on observed data. Besides, assumption of normality is not strictly required (Johnson and Wichern 2002). In the current study, this method is employed to compute aggregate indices for measuring household environmental health hazards and access to health services from several indicators. This multivariate data reduction technique involves generating a few set of orthogonal linear combinations of the original variables, called principal components, which capture much of the variability in the original data set. The component with the largest variance is used to represent the composite index (Filmer and Pritchett 2001).

Suppose we have p indicators $x_1$ $x_2$,..,$x_p$ . and $PC_1$,$PC_2$, …, $PC_p$ are the p principal components in order of decreasing explained variance, which are determined by the formula below. Then, the technique determines $a_{ij}$s, called factor loadings (weights) such that the principal components are orthogonal. The composite index is represented by $PC_1$, which captures the largest variance (or information) shared by the original variables.

$$PC_1 = a_{11}x_1 + a_{12}x_2 + .... + a_{1p}x_p$$

$$PC_2 = a_{21}x_1 + a_{22}x_2 + .... + a_{2p}x_p$$

.

.

.

$$PC_p = a_{p1}x_1 + a_{p2}x_2 + .... + a_{pp}x_p$$

#### 3.3.1. Index of household environmental health hazards

Using principal component analysis, a composite index is constructed to measure the level of health hazards in the household environment based on seven indicators: i) whether the household has access to improved source of water for drinking; ii) whether the water source is in the premise or not; iii) whether the household has access to improved toilet facilities; iv) whether the household lives in a house with finished floor; v) whether the household lives in a house with finished wall; vi) whether the household lives in a house with finished roof and vii) whether the household uses improved (non-biomass) source of energy for cooking.

The above indicators are a result of transformations of original variables in the data sets in the following manner. Improved water sources include piped into dwelling, piped to yard/plot, piped from the neighbourhood, public tap/stand pipe, tube well or borehole, protected well, protected spring, rain water, bottled water, village hydraulic. Other sources- including unprotected well, unprotected spring, river, dam, lake, ponds, stream, and canal- are categorized as unimproved sources.

The amount of time in minutes which is needed by the household to get to water sources is used as a proxy for the quantity of water the household might get. This time is applicable only to households whose sources are not on their premises. To accommodate all households, they are categorized into those whose sources are on their premises and those whose sources are not on their premises.

Improved toilet facilities include flush to piped sewer system; flush to septic tank; flush/pour flush to pit, composting toilet; VIP latrine; and pit latrine with a slab. Unimproved facilities include flush/pour flush elsewhere, pit latrine without a slab, bucket and hanging toilet. Households who defecate in the open (bush) are included under the unimproved category.

Finished floor materials include parquet, polished wood, vinyl/ asphalt strips, ceramic tiles, cement, carpet, *lino/gerflex*, and *carrlage*. Other materials (including wood plank, bamboo, earth; sand; dung, broken bricks) are considered as unfinished floor.

Finished wall materials include cement, stone with lime/cement, bricks, cement blocks, covered adobe, and wood planks/shingles. Other rudimentary and natural materials, including bamboo with mud, stone with mud, uncovered adobe, plywood, cardboard, reused wood, cane, palm, trunks, and dirt are categorized as unfinished.

Finished roof materials include metal, wood, zinc/cement fibre, tiles, cement, and shingles. Other rudimentary and natural materials, including rustic mat, palm, bamboo, wood planks, cardboard roof, thatch/palm leaf, sod, and straw are categorized as unfinished.

Improved or non-biomass sources of energy include electricity, LPG, biogas, kerosene, gasoline and jelly. On the other hand, wood, crop residue, dung cake, straw, lignite, charcoal, and sawdust are considered as unimproved sources.

For all the above categorical indicators, dummies are created such that one represents improved/finished category and zero otherwise. For all these indicators, frequencies for the 'other' category in the original variables are too small; and hence, they are assigned a value of zeros. Finally, principal component analysis is used to construct the composite index from these indicators to measure the level of health hazards in the household environment.

Using the method described above, the result for factor loadings corresponding to the above indicators is presented in

Table 3.3. It shows that the explained variance by the first principal component (i.e. the index of household environmental health hazards) ranges from 49 per cent in Rwanda to 76 per cent in Zimbabwe. In general, the factor loadings (weights) for all indictors are similar across countries. In particular, the type of floor and roof tend to have larger factor loadings than other indicators. On the other hand, the type of source for drinking water tends to have less weight for several countries. The signs of the factor loadings for all indicators are positive, as it is expected. This implies that a large value of the index indicates a lesser level of health hazards in the household environment. However, in further analysis, the index is reversed so that interpretation in terms of an increment in the index can be dealt with ease in later chapters.

**Table 3.3. Factor loadings for constructing index of household environmental health hazards**

| Indicators | Burkina Faso | Burundi | Cameroon | Cote d'Ivoire | Ethiopia | Gabon | Guinea | Malawi | Niger | Rwanda | Senegal | Zimbabwe |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water source** | 0.27 | 0.24 | 0.35 | 0.30 | 0.35 | 0.35 | 0.31 | 0.24 | 0.32 | 0.27 | 0.27 | 0.29 |
| **Time to water source** | 0.37 | 0.48 | 0.34 | 0.38 | 0.40 | 0.39 | 0.33 | 0.37 | 0.40 | 0.46 | 0.35 | 0.36 |
| **Toilet** | 0.43 | 0.31 | 0.39 | 0.40 | 0.38 | 0.39 | 0.43 | 0.36 | 0.41 | 0.32 | 0.41 | 0.38 |
| **Floor** | 0.42 | 0.48 | 0.44 | 0.42 | 0.42 | 0.42 | 0.46 | 0.46 | 0.41 | 0.51 | 0.39 | 0.40 |
| **Wall** | 0.37 | 0.40 | 0.37 | 0.44 | 0.36 | 0.31 | 0.43 | 0.29 | 0.43 | 0.39 | 0.41 | 0.38 |
| **Roof** | 0.40 | 0.40 | 0.36 | 0.41 | 0.38 | 0.34 | 0.42 | 0.44 | 0.38 | 0.39 | 0.40 | 0.41 |
| **Cooking** | 0.36 | 0.26 | 0.38 | 0.27 | 0.36 | 0.43 | 0.18 | 0.44 | 0.27 | 0.22 | 0.39 | 0.42 |
| **Explained variance** | 0.60 | 0.58 | 0.65 | 0.62 | 0.73 | 0.63 | 0.59 | 0.59 | 0.71 | 0.49 | 0.69 | 0.76 |

### 3.3.2. Index of accessibility of health services in the community

The index of accessibility of health services in the community is constructed from five indicators using principal component analysis: i) the proportion of mothers who received antenatal care prior to last birth from a medical professional (doctor and/or mid-wife and/or nurse) in the community; ii) the average number of antenatal visits prior to the last birth by mothers in the community; iii) the proportion of mothers who were assisted by a medical professional (doctor and/or mid-wife and/or nurse) during delivery for the last birth iv); the proportion of mothers who received postnatal care from a medical professional (doctor and/or mid-wife and/or nurse) within two months after the last birth in the community; and v) the average number of immunizations a child of age 1-4 received in the community. The first three indicators are restricted to last births of women for births within the last five years from the survey date. On the other hand, delivery assistance by a medical professional applies to three or more deliveries of a mother within the last five years from the survey date. To avoid bias due to duplication of similar information from the same mother for more than one maternity in the period and also to ensure uniformity with the first three indicators, only the information for the last birth is used. For the last indicator, the immunizations are selected based on WHO recommendation. The recommended immunizations are BCG, DPT1, DPT2, DPT3, Polio1, Polio2, Polio3, and Measles. This information is not applicable for children who are not alive.

**Table 3.4. Factor loadings for constructing index of health service accessibility**

| Indicators | Burkina Faso | Burundi | Cameroon | Cote d'Ivoire | Ethiopia | Gabon | Guinea | Malawi | Niger | Rwanda | Senegal | Zimbabwe |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Prenatal care** | 0.54 | 0.29 | 0.51 | 0.48 | 0.51 | 0.54 | 0.47 | 0.57 | 0.48 | 0.54 | 0.34 | 0.55 |
| **Antenatal visits** | 0.33 | 0.57 | 0.51 | 0.47 | 0.53 | 0.49 | 0.44 | 0.55 | 0.48 | 0.57 | 0.49 | 0.56 |
| **Delivery assistance** | 0.53 | 0.59 | 0.54 | 0.49 | 0.48 | 0.53 | 0.48 | 0.61 | 0.44 | 0.49 | 0.51 | 0.51 |
| **Postnatal care** | 0.52 | 0.49 | ** | 0.36 | 0.27 | 0.24 | 0.47 | ** | 0.41 | * | 0.48 | 0.35 |
| **Child immunization** | 0.22 | * | 0.42 | 0.43 | 0.38 | 0.36 | 0.36 | * | 0.42 | 0.39 | 0.39 | * |
| **Explained variance** | 0.61 | 0.41 | 0.67 | 0.6 | 0.64 | 0.55 | 0.67 | 0.5 | 0.7 | 0.43 | 0.54 | 0.5 |

* The indicator is excluded because it undermines the explained variance substantially.
**Postnatal care is not included because of large number of missing values for Cameroon and Malawi

The factor loadings for these indicators are presented in Table 3.4. The average number of immunizations a child of age 1 to 4 received and the proportion of mothers who received postnatal care from medical professional for their last birth have relatively lower weights. Including the last indicator (average number of immunizations) in the construction of the index leads to a little explained variance in Burundi, Malawi and Zimbabwe, while the fourth indicator (postnatal care) causes a similar problem in Rwanda. For these countries, the respective indicators are dropped from the calculation of the index for the above reason.

### 3.4. Methods for modelling covariates of child mortality

Several methods have been used in the study of child survival. Models for time to event data which are commonly called hazard models are the most popular ones in the literature for modelling the effects of covariates of child survival. In fact, numerous studies that are cited in the previous chapter involve such models (Trussell and Hammerslough 1983; Bolstad and Manda 2001; Boco 2010). Scholars give a number of reasons for making preference for hazard models over standard techniques, including Ordinary Least Square (OLS) methods and binary regression models. OLS and binary regression are limited to handle key features of survival time data, including censoring. In addition, the use of binary regression models leads loss of information, which is a result of dichotomizing the mainly continuous nature of lifetime data (Allison 1982). By contrast, the methodological literature indicates that using hazard models accounts the key features of survival data, including the sequential nature of the variable and censoring by using the hazard function to model covariates. In addition, the use of maximum likelihood or partial likelihood resolves the problem of using OLS.

The previous paragraph highlights why hazard models are suitable to the nature of lifetime data. Another concern in social science studies, in particular the study of child survival, is how the modelling approach accounts for the hierarchy in the data structure. In this regard, the development of multilevel methods contributes by solving some of the problems (aggregation bias and misestimating) faced by past studies using classical methods that do not account the nature of data structures (Raudenbush and Bryk 2002). Multilevel models are commonly used in quantitative social science researches. Indeed, in particular subjects like public health, it is said to contribute improved modelling of neighbourhood effects on individual health (Subramanian 2004). In many surveys, we find human subjects nested in various geographically existing clusters. In demographic studies, human subjects may be found clustered at the household-level and households are clustered in communities etc. The aim of multilevel analysis is to properly incorporate this peculiarity in the data structure. It makes use of information characterizing the units at each level to model the effects of clustering of units at the given level. This makes it possible to understand the contribution of variability at each level towards the total variability in the response (Raudenbush and Bryk 2002).

We have noted in the first paragraph that many mortality studies share in using hazard models; however, they differ in the specification of the model used in various ways, including in the choice of the shape of the baseline hazard function, continuous versus discrete time and single level versus hierarchical survival models. Even, within the class of multilevel models, different researchers use different orders of hierarchy with similar sources of data. In his commentary essay to critics on the use of multilevel models for causal inference, Subramanian (2004) notes the neglect of multiplicity of data structure in the use of multilevel models in applied researches. He added that though there is a possibility of modelling complex hierarchical data structures with reasonable assumptions, researchers focus mainly on two-level models in that they ignore the possibility of using more than two-level models, which might enlighten understanding of true neighbourhood differences. He further concludes that a proper use of this method offers additional power, description and precision to understand causal neighbourhood effects.

Obviously, in view of the above discussion, a careful consideration in the choice of a proper model is crucial for the study to be credible. In particular, the above discussion suggests that some methods are more plausible and informative than others to the peculiarities of certain data sets. In this regard, I believe that the use of the multilevel discrete-time hazard model is more appealing than others. The following chapter outlines the basic concepts related to this model.

## 3.5. The basics of survival data analysis

### 3.5.1. Basic concepts

Lifetime data exists in various fields, including demography. For instance, demographic researches which involve the study of birth intervals and time to first marriage generate such type of data. In particular, mortality which is one of the major areas of demographic enquiry, involves some form of lifetime data. In general, lifetime (survival time) is the time length from a well-defined initial condition until some event (usually known as failure) occurs. Survival data are a result of such observational process involving the recording of time.

Lifetime data have two key features. First, lifetime can take only non-negative values and usually the shape of the distribution is skewed. Second, the event of interest might not occur for some subjects in the study period; hence, their survival times are not completely known. For such subjects and others in which their survival times are not known completely, their survival times are said to be censored.

Three types of censored observations are known. One, if the event of interest occurs after the end of the study period for a subject or a subject is lost to follow up within the study period, the life time of the subject is said to be right-censored. Second, if a subject is at risk of the event before the beginning of the study, the subject's survival time is said to be left-censored. Third, the event is realized in the study period; however, the exact time is not known in that the occurrence of the event is known to be within an interval of time. Such lifetimes are called interval censored. The peculiarity of interval censoring is a problem of precisely identifying the exact time of event occurrence. For instance, birth date is expressed in terms of year and month in DHS surveys. So strictly speaking, construction of survival time data from birth history module to study the risk of dying before age five results in interval censored lifetimes.

Another important aspect of survival time data is whether it is measured in continuous or discrete time scale. This information is helpful to choose an appropriate model. Continuous lifetime data result when the exact durations of observations are known. On the other hand, discrete lifetime data can result in two ways. First, data might be generated by grouping of a continuous scale because of interval censoring. Second, some lifetime data are intrinsically discrete in that they are measured on a discrete time scale like annually, quarterly, etc. In this study, the survival data are a result of using the first approach in that the lifetimes are categorized into groups as described in the first section of this chapter. This categorization minimizes the imprecision due to birth date recording in months and year only and also due to potential age misreporting.

The analysis of survival data ranges from describing the distribution of survival times using median to assessing the effects of covariates. The methods for such analysis are based on some important functions, including the distribution function of the survival data. The following sub-section defines these functions and highlights some of their relationships.

### 3.5.2. The survivor and hazard functions

Suppose the random variable Y, the functions f(y) and F(y) represent the survival time in the continuous scale, its probability density and cumulative distribution functions, respectively. Obviously, from the statistical definition of a distribution function, the probability of failure before a specific time *y* is equal to F(*y*). It is also called the failure function. Mathematically, it is represented by the following integral:

$$F(y) = P(Y < y) = \int_0^y f(t)dt$$

An important function related to the failure function is the survivor function. It is denoted as S(y). It represents the probability that the survival time will be greater than or equal to y. Mathematically, it can be expressed in terms of the failure function:

$$S(y) = P(Y \geq y) = 1 - F(y)$$

Another important function which plays a key role in survival analysis is the hazard function. It is denoted as h(y). It is the probability of an event, say death, in an infinitesimally small time between y and (y + Δy) given survival up to time y. Mathematically, it is represented in the following way:

$$h(y) = \lim_{\Delta y \to 0} \frac{P(y \leq Y < y + \Delta y \mid Y > y)}{\Delta y} = \frac{f(y)}{S(y)}$$

The hazard rate is related to chances of making a transition out of the current state at each instant (or time point) conditional on survival up to that point.

The above definitions for hazard and survivor functions hold for continuous survival data. However, as previously noted, some survival data are either grouped or inherently discrete. For such type of data, analogous definitions exist. In particular, definition of the hazard rate for discrete time survival data and methods for modelling covariates are dealt in the following sections.

## 3.6. Multilevel discrete-time hazard model

### 3.6.1. General concepts

The previous section gives a brief account of the basic foundation of survival data analysis, which is useful for understanding modelling covariates based on the hazard function. This section briefly outlines methods, which extend the concepts covered in the previous section to accommodate hierarchically structured discrete-time survival data. In particular, the objective of this section is to give an outline of the multilevel discrete-time hazard model, which is used to model the covariates of child survival in this study.

First, it is important to define the discrete version of the hazard rate to specify this model. The discrete-time hazard rate is defined as the conditional probability that a randomly selected individual will experience the target event in a given time period, given that he or she did not experience the event prior to the given period. Suppose T represents the underlying discrete-time random variable, which takes the discrete time interval values 1, 2,…,5 and i indexes the child and can take the values 1,2,…,n where n stands for the sample size. Then the discrete time hazard for the $i^{th}$ child at time t is mathematically expressed as follows:

$$h_{it} = P(T_i = t \mid T_i \geq t)$$

Two types of methods are usually used to model the dependence of the hazard on predictors. The first is based on the logit transform of the hazard rate due to Cox (1972) and the second approach is based on log-log transform of the hazard rate due to Prentice and Gloeckler (1978 ). Both models are said to give similar results. An advantage of the first approach is due to its appealing interpretation for model parameters. In this study, the first approach is used. Based on the given choice of link function for the hazard rate, a single level discrete-time hazard model is represented mathematically in the following way:

$$\log it(h_{it}) = \log\left[\frac{h_{it}}{1-h_{it}}\right] = \alpha + \alpha_1 d_{1it} + \alpha_2 d_{2it} + \alpha_2 d_{2it} + \alpha_3 d_{3it} + \alpha_4 d_{4it} + x'_{it}\beta$$

where α represents the intercept and $\alpha_t$ is the coefficient of the dummy variable, $d_t$, for $t^{th}$ time interval (or age). These coefficients describe the nature of the baseline hazard. $X_{it}$ represents a vector of values for covariates for the $i^{th}$ individual at time t. β represents the corresponding vector of parameters.

The statistical literature indicates that fitting of this discrete time hazard model can be achieved using the methods of generalized linear models. In particular, Allison (1982) and Singer and Willett (1993) demonstrate the applicability of the result using any logistic regression program. More specifically, they show the equivalence of the likelihood of this model with the likelihood of Bernoulli trials defined by an event indicator. The implementation of this procedure requires the restructuring of the person-oriented data into person-period data by creating an event indicator variable. This procedure is called episode splitting. For a given individual, the event indicator takes a value of one when the event occurs in the given interval otherwise zero. For instance, the event for an individual is occurred, say in the third interval, then the individual is assigned three observations. The first two observations are assigned zeros and the last observation is assigned one. The individual's characteristics and the time interval indicators are also matched in the specified time period.

This model does not require explicit assumption for the baseline hazard; however, the method assumes that effects of predictors are independent of time. This so-called proportionality assumption holds in the odds of the hazard (not in the hazard); hence, a coefficient of a predictor is interpreted as the change in log-odds of the hazard for a unit change in the given predictor (Rabe-Hesketh and Skrondal 2008).

Furthermore, Barber, Murphy, Axinn and Maples (2000) demonstrate analogous result for fitting multilevel discrete-time hazard model based on multilevel logistic model. In this study, children are nested in communities. Hence, children and communities form the first- and second-level units, respectively. The two-level discrete-time hazard model with random intercept is represented as follows:

$$\log it(h_{ijt}) = \log\left[\frac{h_{ijt}}{1-h_{ijt}}\right] = \alpha + \alpha_1 d_{1ijt} + \alpha_2 d_{2ijt} + \alpha_2 d_{2ijt} + \alpha_3 d_{3ijt} + \alpha_4 d_{4ijt} + x'_{ijt}\beta + u_j$$

In this model, $x_{ijt}$ represents a vector of values for covariates, including community-level characteristics for the $i^{th}$ child in community j at time t. As in the individual-level model, some or all predictors can be fixed or time varying. Its corresponding vector of parameters β stands for the fixed part of the model. On the other hand, $u_j$ represents the random effect for the $j^{th}$ community in the model. The random effects ($u_j$s) are assumed to have independent normal distributions with constant variance $\psi$. This assumption is written in a mathematical notation as follows:

$$u_j \overset{iid}{\sim} N(0,\psi)$$

The fitting of this multilevel discrete-time hazard model is achieved using its corresponding multilevel binary model using the extended person-period data described earlier. This model is fitted by using the Stata command xtlogit. The procedure involves maximum likelihood estimation using numerical integration called adaptive quadrature (Rabe-Hesketh and Skrondal 2012).

To assess the contribution of clustering at the community level to the total variability of the response, the following intra-class correlation formula is adopted (Rabe-Hesketh and Skrondal 2012):

$$ICC = \frac{\psi}{\frac{\pi^2}{3} + \psi}$$

### 3.6.2. Inference for model parameters

The general asymptotic results for large samples for likelihood based inference, including likelihood ratio and Wald tests based on a chi-square and standard normal distributions are applicable for testing and interval estimation regarding model parameters (Rabe-Hesketh and Skrondal 2012). To test the significance of a regression coefficient, say β, the Wald test procedure is as follows: $H_0$: β=0 versus $H_1$: β≠0. The test statistic to test this hypothesis has a standard normal distribution:

$$Z = \frac{\hat{\beta} - 0}{s.e(\hat{\beta})} \underset{H_0}{\sim} N(0,1)$$

Large values of z in absolute terms show evidence against the null hypothesis in favour of the alternative. Specifically, decision can be reached by comparing the observed statistic with a table value of the standard normal distribution for pre-specified level of significance. Alternatively, a p-value can be used to quantify the amount of evidence against the null hypothesis.

Using the distribution of the previous statistic, a 95 per cent confidence interval for a regression coefficient, β is given by

$$\hat{\beta} \pm 1.96 \times s.e(\hat{\beta})$$

Exponentiation of the lower and upper limits of this interval estimate using the natural base (e) gives the corresponding 95 per cent confidence interval for the odds ratio. The likelihood-ratio test can be used to compare models and also test the significance of the random effect (i.e. its variance).

# 4. RESULT

Chapter 4 presents the result of the study. It is organized into three sections. The first section describes distribution of under-five deaths in the samples by covariates included in the study. The second section gives a preliminary context based on descriptive graph and table to see the relationship between age pattern of death and level of household environmental health hazards. The third section presents fitted multilevel discrete-time hazard models. In all sections, the presentation gives central importance on general features and peculiarities. Hence, details for each country are kept to a minimum.

Before undertaking the major data analysis, a general assessment of the quality of data is conducted. In particular, the nature of missing observations is assessed for each covariate included in the study. Appendix 1shows the per cent distribution of missing values by the survival status of the child. In general, the percentages of missing values are too small and have no any pattern by the survival status of the child. I believe that excluding these missing values does not compromise the result of the study appreciably. Moreover, since the modelling approach depends on a discrete-time scale, the traditional demographic techniques for checking age accuracy (including heaping, age miss-reporting) are less important.

## 4.1. Sample characteristics

Table 4.1 presents the distributions of births and deaths by covariates for all countries included in the study. The numbers under the birth columns represent un-weighted per cents of births in the given category of the covariate out of the total samples of births while the figures under death columns represent weighted per cents of under-five deaths out of the births within the given category. Total births represent the total sample size for each country in the study. This includes all births that took place within five years from the survey date, except for the few cases which are excluded due to missing values for at least for one of the variables. Sample size ranges from 5,547 births in Zimbabwe to 19,894 births in Malawi. The following sub-sections present a descriptive assessment on the relationship between various covariates and the percentage of under-five deaths. Continuous covariates are categorized into three intervals to simplify description. The categorization involves grouping the distribution of the covariates using 33.3 and 66.6 percentile points as cut points. This specification applies only to descriptive analysis.

**Table 4.1. Per cent distributions of births and deaths by covariates**

| Covariates | Burkina Faso | | Burundi | | Cameroon | |
|---|---|---|---|---|---|---|
| | Birth* | Death* | Birth | Death | Birth | Death |
| Total births** | 14994 | | 7625 | | 11630 | |
| **Household health hazard level** | | | | | | |
| Low | 28.6 | 6.2 | 26.6 | 4.7 | 17.7 | 5.8 |
| Medium | 31.1 | 8.5 | 39.3 | 7.1 | 43.9 | 7.8 |
| High | 40.3 | 10.9 | 34.2 | 8.1 | 38.3 | 10.9 |
| **Sex** | | | | | | |
| Male | 50.9 | 9.4 | 50.8 | 7.5 | 49.5 | 8.7 |
| Female | 49.2 | 8.4 | 49.2 | 6.4 | 50.5 | 8.6 |
| **Birth order and interval** | | | | | | |
| 1st | 18.7 | 9.1 | 21.0 | 8.5 | 22.9 | 8.1 |
| 2nd & >= 2 years | 15.4 | 6.4 | 13.2 | 6.4 | 15.3 | 6.4 |
| 2nd & < 2 years | 2.1 | 13.8 | 5.3 | 7.6 | 3.8 | 12.1 |
| 3+ & >= 2 years | 56.2 | 7.9 | 49.5 | 5.5 | 45.9 | 7.7 |
| 3+ & < 2 years | 7.5 | 18.6 | 11.0 | 11.2 | 12.2 | 14.9 |
| **Mother's age at birth** | | | | | | |
| Less than 20 years | 14.4 | 11.3 | 9.0 | 8.4 | 20.2 | 9.9 |
| 20-34 | 69.6 | 8.4 | 72.5 | 6.6 | 68.3 | 8.4 |
| 35 or more years | 16.0 | 8.8 | 18.6 | 7.4 | 11.5 | 8.3 |
| **Mother's education** | | | | | | |
| No education | 83.5 | 9.5 | 49.4 | 8.3 | 24.8 | 12.4 |
| Primary | 11.2 | 6.3 | 41.0 | 5.8 | 41.9 | 8.5 |
| Secondary and above | 5.4 | 4.2 | 9.7 | 2.9 | 33.3 | 5.5 |
| **Mother's HIV status** | | | | | | |
| Negative | 49.8 | 9.2 | 47.9 | 6.8 | 43.9 | 8.6 |
| Positive | 0.5 | 19.8 | 1.3 | 8.6 | 2.2 | 15.6 |
| Not tested | 49.8 | 8.5 | 50.9 | 7.0 | 53.9 | 8.5 |
| **Household wealth** | | | | | | |
| Poor | 40.7 | 10.7 | 39.1 | 8.1 | 44.8 | 11.1 |
| Middle | 21.9 | 9.0 | 18.8 | 7.0 | 21.5 | 7.7 |
| Rich | 37.4 | 6.7 | 42.1 | 5.7 | 33.6 | 6.1 |
| **Residence** | | | | | | |
| Urban | 21.6 | 5.8 | 17.6 | 4.8 | 40.0 | 6.9 |
| Rural | 78.5 | 9.5 | 82.4 | 7.1 | 60.0 | 10.0 |
| **Community level of health service** | | | | | | |
| Low | 38.6 | 10.7 | 34.5 | 8.5 | 43.8 | 10.9 |
| Medium | 34.0 | 8.7 | 34.1 | 6.7 | 32.2 | 7.7 |
| High | 27.4 | 6.7 | 31.5 | 5.2 | 23.9 | 5.9 |
| **Community level of mothers' education** | | | | | | |
| Low | 39.2 | 10.6 | 37.3 | 8.2 | 44.6 | 11.1 |
| Medium | 38.1 | 8.6 | 33.4 | 6.6 | 32.5 | 7.8 |
| High | 22.7 | 5.9 | 29.3 | 5.3 | 23.0 | 4.8 |
| **Community level of poverty** | | | | | | |
| Low | 25.5 | 5.8 | 32.3 | 5.3 | 31.3 | 5.8 |
| Medium | 36.2 | 8.2 | 34.1 | 7.0 | 26.0 | 9.1 |
| High | 38.3 | 11.3 | 33.6 | 8.1 | 42.7 | 10.6 |

*Birth columns represent un-weighted percentages but death columns represent weighted percentages.
**Total births row represent the sample sizes in absolute numbers.

**Table 4.1. Continued**

| Covariates | Cote d'Ivoire | | Ethiopia | | Gabon | |
|---|---|---|---|---|---|---|
| | Birth* | Death* | Birth | Death | Birth | Death |
| Total births** | 7713 | | 11259 | | 5995 | |
| **Household health hazard level** | | | | | | |
| Low | 23.7 | 7.0 | 20.1 | 5.9 | 23.4 | 5.4 |
| Medium | 39.4 | 8.6 | 44.1 | 6.3 | 34.1 | 5.3 |
| High | 36.9 | 9.0 | 35.8 | 8.3 | 42.5 | 5.5 |
| **Sex** | | | | | | |
| Male | 50.5 | 10.7 | 51.2 | 7.8 | 50.0 | 6.3 |
| Female | 49.5 | 5.9 | 48.8 | 6.0 | 50.0 | 4.3 |
| **Birth order and interval** | | | | | | |
| 1st | 21.9 | 7.6 | 18.9 | 6.9 | 24.5 | 6.1 |
| 2nd & >= 2 years | 17.2 | 6.3 | 12.7 | 6.2 | 15.8 | 4.6 |
| 2nd & < 2 years | 2.7 | 6.9 | 4.2 | 8.2 | 4.2 | 9.5 |
| 3+ & >= 2 years | 49.2 | 7.9 | 49.8 | 5.8 | 44.2 | 3.5 |
| 3+ & < 2 years | 9.0 | 16.6 | 14.3 | 12.0 | 11.3 | 11.5 |
| **Mother's age at birth** | | | | | | |
| Less than 20 years | 16.9 | 8.1 | 14.3 | 8.9 | 22.7 | 5.1 |
| 20-34 | 69.1 | 8.0 | 72.1 | 6.6 | 62.3 | 5.4 |
| 35 or more years | 14.0 | 9.8 | 13.7 | 7.0 | 15.1 | 5.8 |
| **Mother's education** | | | | | | |
| No education | 67.7 | 8.5 | 71.5 | 7.4 | 5.9 | 7.7 |
| Primary | 23.0 | 8.7 | 24.9 | 6.2 | 40.3 | 5.8 |
| Secondary and above | 9.3 | 6.0 | 3.6 | 3.7 | 53.8 | 5.0 |
| **Mother's HIV status** | | | | | | |
| Negative | 46.4 | 7.7 | 94.7 | 7.1 | 64.4 | 5.0 |
| Positive | 1.7 | 18.0 | 1.1 | 5.7 | 3.1 | 3.8 |
| Not tested | 51.9 | 8.5 | 4.2 | 4.1 | 32.4 | 6.3 |
| **Household wealth** | | | | | | |
| Poor | 45.2 | 9.0 | 50.9 | 8.2 | 68.6 | 5.6 |
| Middle | 23.7 | 7.2 | 16.6 | 6.6 | 13.5 | 5.3 |
| Rich | 31.1 | 8.0 | 32.6 | 5.5 | 17.9 | 5.2 |
| **Residence** | | | | | | |
| Urban | 33.1 | 7.3 | 14.5 | 6.2 | 61.3 | 5.2 |
| Rural | 66.9 | 8.9 | 85.6 | 7.1 | 38.7 | 6.3 |
| **Community level of health service** | | | | | | |
| Low | 44.8 | 9.3 | 42.0 | 7.8 | 33.3 | 6.4 |
| Medium | 30.9 | 7.2 | 37.1 | 6.5 | 32.7 | 4.3 |
| High | 24.3 | 7.9 | 21.0 | 5.9 | 34.0 | 5.8 |
| **Community level of mothers' education** | | | | | | |
| Low | 45.1 | 9.3 | 58.0 | 7.9 | 35.6 | 6.8 |
| Medium | 32.7 | 7.8 | 20.6 | 6.7 | 32.9 | 5.1 |
| High | 22.2 | 7.4 | 21.4 | 5.1 | 31.6 | 5.2 |
| **Community level of poverty** | | | | | | |
| Low | 25.1 | 7.4 | 24.5 | 5.4 | 35.9 | 5.4 |
| Medium | 37.5 | 9.4 | 36.3 | 6.7 | 35.5 | 4.7 |
| High | 37.4 | 8.0 | 39.3 | 8.7 | 28.6 | 7.1 |

*Birth columns represent un-weighted percentages but death columns represent weighted percentages.
**Total births row represent the sample sizes in absolute numbers.

## Table 4.1. Continued

| Covariates | Guinea | | Malawi | | Niger | |
|---|---|---|---|---|---|---|
| | Birth* | Death* | Birth | Death | Birth | Death |
| Total births** | 7012 | | 19894 | | 12491 | |
| **Household health hazard level** | | | | | | |
| Low | 30.2 | 5.5 | 31.7 | 8.1 | 30.2 | 5.9 |
| Medium | 34.7 | 9.4 | 33.4 | 9.2 | 8.1 | 7.8 |
| High | 35.1 | 11.0 | 35.0 | 8.5 | 61.7 | 8.9 |
| **Sex** | | | | | | |
| Male | 51.8 | 9.4 | 50.0 | 9.6 | 50.7 | 8.4 |
| Female | 48.2 | 8.1 | 50.0 | 7.5 | 49.4 | 7.8 |
| **Birth order and interval** | | | | | | |
| 1st | 21.7 | 9.6 | 19.7 | 9.6 | 14.8 | 9.2 |
| 2nd & >= 2 years | 15.5 | 6.8 | 15.5 | 6.0 | 11.0 | 5.9 |
| 2nd & < 2 years | 2.2 | 10.4 | 3.2 | 14.3 | 3.6 | 9.2 |
| 3+ & >= 2 years | 53.2 | 7.9 | 53.4 | 7.6 | 54.9 | 7.1 |
| 3+ & < 2 years | 7.5 | 15.8 | 8.2 | 14.4 | 15.7 | 11.7 |
| **Mother's age at birth** | | | | | | |
| Less than 20 years | 21.3 | 10.1 | 18.0 | 10.1 | 16.1 | 8.8 |
| 20-34 | 63.9 | 8.2 | 69.4 | 7.9 | 69.9 | 7.6 |
| 35 or more years | 14.8 | 9.0 | 12.6 | 10.1 | 14.0 | 9.5 |
| **Mother's education** | | | | | | |
| No education | 78.3 | 9.2 | 16.9 | 8.7 | 83.0 | 8.3 |
| Primary | 11.8 | 9.2 | 69.5 | 8.8 | 11.0 | 7.1 |
| Secondary and above | 9.9 | 4.8 | 13.6 | 7.2 | 6.1 | 6.1 |
| **Mother's HIV status** | | | | | | |
| Negative | 51.6 | 8.9 | 29.3 | 6.3 | 46.6 | 7.9 |
| Positive | 0.9 | 11.4 | 3.0 | 16.6 | 0.2 | 11.7 |
| Not tested | 47.6 | 8.6 | 67.7 | 9.1 | 53.2 | 8.3 |
| **Household wealth** | | | | | | |
| Poor | 44.6 | 10.4 | 45.1 | 8.6 | 36.1 | 8.5 |
| Middle | 20.5 | 10.2 | 22.6 | 8.3 | 18.7 | 8.2 |
| Rich | 35.0 | 5.8 | 32.3 | 8.7 | 45.2 | 7.6 |
| **Residence** | | | | | | |
| Urban | 28.9 | 5.8 | 9.5 | 9.2 | 21.8 | 4.4 |
| Rural | 71.1 | 9.8 | 90.5 | 8.4 | 78.2 | 8.6 |
| **Community level of health service** | | | | | | |
| Low | 38.7 | 10.9 | 36.9 | 9.2 | 34.6 | 8.7 |
| Medium | 33.8 | 9.0 | 34.5 | 8.5 | 35.3 | 8.4 |
| High | 27.5 | 5.7 | 28.6 | 7.8 | 30.1 | 6.8 |
| **Community level of mothers' education** | | | | | | |
| Low | 39.9 | 10.7 | 39.1 | 8.5 | 45.9 | 8.0 |
| Medium | 34.3 | 9.2 | 36.3 | 8.9 | 27.2 | 9.2 |
| High | 25.8 | 5.2 | 24.6 | 8.2 | 26.9 | 6.6 |
| **Community level of poverty** | | | | | | |
| Low | 26.6 | 5.5 | 26.4 | 8.5 | 28.5 | 5.9 |
| Medium | 36.9 | 8.5 | 36.9 | 8.7 | 38.9 | 8.8 |
| High | 36.5 | 11.3 | 36.7 | 8.5 | 32.6 | 8.4 |

*Birth columns represent un-weighted percentages but death columns represent weighted percentages.
**Total births row represent the sample sizes in absolute numbers.

**Table 4.1. Continued**

| Covariates | Rwanda | | Senegal | | Zimbabwe | |
|---|---|---|---|---|---|---|
| | Birth* | Death* | Birth | Death | Births | Death |
| Total births** | 8939 | | 12301 | | 5547 | |
| **Household health hazard level** | | | | | | |
| Low | 15.7 | 4.0 | 30.9 | 4.3 | 31.5 | 5.9 |
| Medium | 30.8 | 5.1 | 35.2 | 5.1 | 32.5 | 8.0 |
| High | 53.5 | 6.7 | 33.9 | 6.7 | 36.0 | 6.6 |
| **Sex** | | | | | | |
| Male | 50.9 | 6.2 | 51.5 | 5.7 | 50.5 | 7.9 |
| Female | 49.1 | 5.4 | 48.6 | 4.6 | 49.5 | 5.8 |
| **Birth order and interval** | | | | | | |
| 1st | 25.1 | 6.0 | 21.5 | 4.9 | 32.2 | 6.0 |
| 2nd & >= 2 years | 13.7 | 5.7 | 14.3 | 4.6 | 24.1 | 5.3 |
| 2nd & < 2 years | 5.5 | 6.7 | 3.5 | 5.9 | 2.5 | 6.8 |
| 3+ & >= 2 years | 46.3 | 4.6 | 50.4 | 4.6 | 37.8 | 7.8 |
| 3+ & < 2 years | 9.4 | 10.6 | 10.3 | 9.0 | 3.4 | 15.4 |
| **Mother's age at birth** | | | | | | |
| Less than 20 years | 6.0 | 6.9 | 16.0 | 5.7 | 19.2 | 7.3 |
| 20-34 | 76.2 | 5.5 | 69.5 | 4.8 | 71.3 | 6.5 |
| 35 or more years | 17.9 | 6.7 | 14.5 | 6.3 | 9.5 | 8.7 |
| **Mother's education** | | | | | | |
| No education | 18.9 | 7.1 | 74.9 | 6.0 | 1.8 | 6.1 |
| Primary | 71.8 | 5.5 | 18.4 | 3.4 | 33.2 | 7.8 |
| Secondary and above | 9.4 | 5.0 | 6.8 | 2.2 | 65.0 | 6.4 |
| **Mother's HIV status** | | | | | | |
| Negative | 48.4 | 6.3 | 35.0 | 5.0 | 71.4 | 4.8 |
| Positive | 1.9 | 14.0 | 0.4 | 11.9 | 15.1 | 13.0 |
| Not tested | 49.8 | 5.0 | 64.6 | 5.2 | 13.4 | 11.4 |
| **Household wealth** | | | | | | |
| Poor | 44.4 | 6.1 | 56.9 | 6.0 | 45.2 | 7.2 |
| Middle | 19.6 | 5.9 | 20.7 | 4.9 | 18.1 | 6.8 |
| Rich | 36.0 | 5.3 | 22.4 | 4.2 | 36.7 | 6.4 |
| **Residence** | | | | | | |
| Urban | 13.5 | 5.6 | 29.6 | 3.8 | 28.9 | 6.9 |
| Rural | 86.5 | 5.8 | 70.4 | 6.0 | 71.1 | 6.8 |
| **Community level of health service** | | | | | | |
| Low | 35.9 | 6.4 | 38.5 | 6.7 | 40.2 | 7.8 |
| Medium | 33.4 | 6.1 | 33.8 | 5.6 | 34.2 | 6.2 |
| High | 30.7 | 4.8 | 27.7 | 3.6 | 25.5 | 6.1 |
| **Community level of mothers' education** | | | | | | |
| Low | 38.9 | 6.6 | 40.2 | 6.1 | 43.1 | 7.1 |
| Medium | 31.3 | 5.8 | 34.9 | 5.4 | 32.3 | 7.7 |
| High | 29.8 | 4.7 | 24.9 | 3.7 | 24.6 | 5.3 |
| **Community level of poverty** | | | | | | |
| Low | 32.7 | 5.1 | 29.3 | 4.1 | 28.6 | 6.5 |
| Medium | 32.9 | 5.5 | 32.6 | 5.2 | 27.9 | 7.2 |
| High | 34.4 | 6.7 | 38.1 | 6.7 | 43.5 | 6.8 |

*Birth columns represent un-weighted percentages but death columns represent weighted percentages.
**Total births row represent the sample sizes in absolute numbers.

#### 4.1.1. Distribution of under-five deaths by household environmental health hazards

In general, the percentage of under-five deaths increases with level of health hazards in the household environment for most countries. In particular, the percentage of under-five deaths among children who are exposed to low level of health hazards varies from 4.0 per cent in Rwanda to 8.1 per cent in Malawi. By contrast, the percentage of under-five deaths among children who are potentially exposed to high levels of health hazards varies from 5.5 per cent in Gabon to 11.0 per cent in Guinea. Contrary to the general pattern which is noted above, the percentage of under-five deaths among children who are potentially exposed to medium level of health hazards is greater than for those who are exposed to high levels of health hazards in Malawi and Zimbabwe.

#### 4.1.2. Distribution of under-five deaths by other covariates

The table shows that the percentage of under-five deaths among male children is consistently higher than for females across countries. Specifically, the percentage of under-five deaths among male children varies from 5.7 per cent in Senegal to 10.7 per cent in Cote d'Ivoire. The corresponding figure among female children varies from 5.4 per cent in Rwanda to 8.6 per cent in Cameroon.

The result suggests that the percentage of under-five deaths is consistently high among children with combinations of high birth-orders and short birth-interval. In particular, this percentage is highest among children with birth-order of three or more and preceding birth-interval of less than 24 months. The percentage of under-five deaths among children under this category is highest in Burkina Faso (18.6 per cent). By contrast, the corresponding highest figure among second-born children with long preceding birth-interval is 6.8 per cent in Guinea. The result also suggests that the percentage of under-five deaths is relatively high among first-born children relative to the corresponding percentage for those children with combinations of second birth-order and long birth-interval.

The percentage of under-five deaths tends to be high among children whose mothers are young (less than 20 years) and old (greater than 34 years) during childbirth compared to the corresponding percentage among children born to mothers between 20 and 34 years old. The percentage of under-five deaths for children born to young mothers is lowest in Gabon (5.1 per cent) and highest in Burkina Faso (11.27 per cent). Contrary to the general non-linear nature of the effect of mothers' age on under-five deaths which is noted above, the percentage of under-five deaths is lowest among children born to young mothers in Gabon and old mothers in Cameroon.

The percentage of under-five deaths is higher among children of HIV-positive mothers compared to children of HIV-negative mothers for most countries. In particular, the percentage of under-five deaths among children of HIV-positive mothers is highest in Burkina Faso (19.8 per cent). Comparatively, the highest percentage of under-five deaths among children of HIV-negative mothers is 9.2 per cent, which is also for the same country. Contrary to the above pattern, the percentage of under-five deaths is less among children whose mothers are HIV-positive compared to children whose mothers are HIV-negative in Ethiopia and Gabon.

In general, the percentage of under-five deaths decreases as the educational level of mothers increases across countries. The percentage of under-five deaths among children whose mothers have no education is highest in Cameroon (12.4 per cent). Comparatively, the corresponding percentage for children of mothers with secondary and above education is highest in Malawi (7.2 per cent). Contrary to the above general relationship for many countries, the percentage of under-five deaths is lowest among children whose mothers have no education in Zimbabwe.

Considering differential by household wealth status, the result suggests that the percentage of under-five deaths declines as household wealth status increases for most countries. Specifically, the percentage of under-five deaths from poor households ranges from 5.6 per cent in Gabon to 11.1 per cent in Cameroon. By contrast, the corresponding distribution from rich households ranges from 4.2 per cent in Senegal to 8.7 per cent in Malawi.

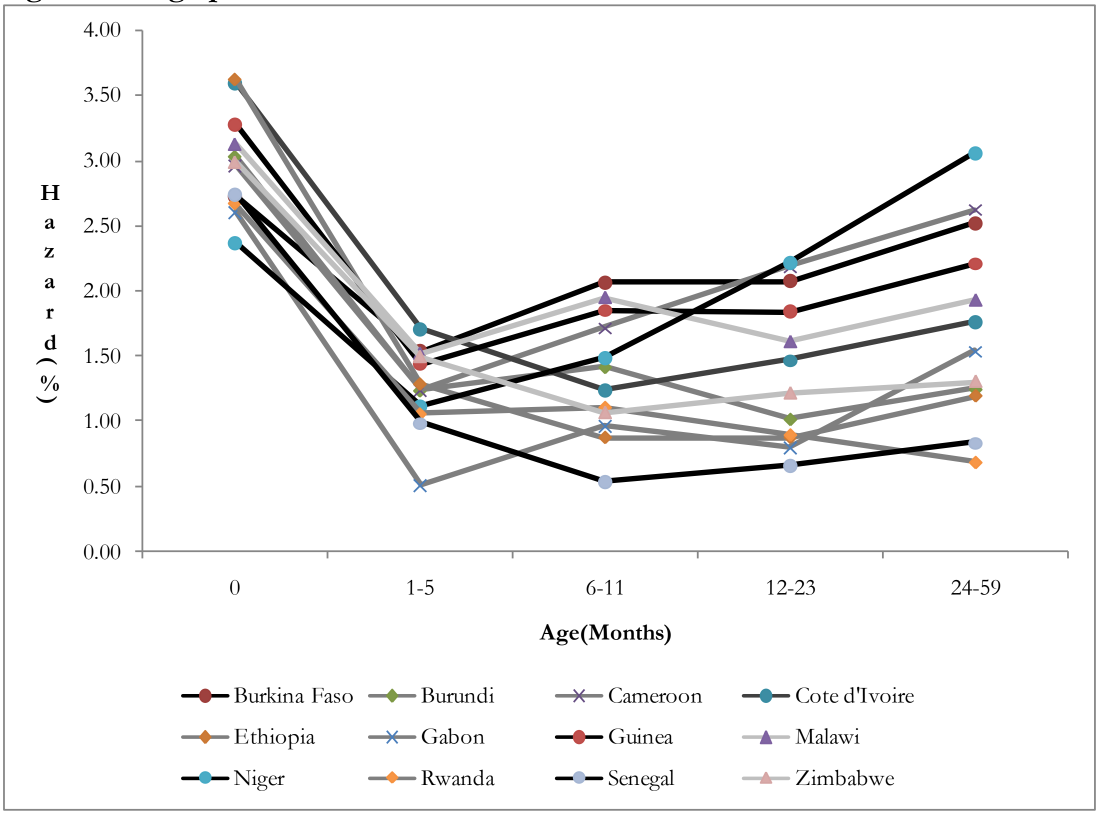
The percentage of under-five deaths is consistently lower in urban than rural communities, except in Malawi where the reverse is true. This figure varies from 3.8 per cent in Senegal to 9.2 per cent in Malawi in urban communities. By contrast, the corresponding figure in rural areas ranges from 5.8 per cent in Rwanda to 10.0 per cent in Cameroon.

In general, the percentage of under-five deaths decreases across countries with the level of health service accessibility in a community. It ranges from 6.4 per cent in Rwanda to 10.9 per cent in Cameroon in communities with low health service accessibility. Comparatively, it varies from 4.8 per cent in Rwanda to 7.9 per cent in Cote d'Ivoire in communities with a high level of health service accessibility.

The percentage of under-five deaths also decreases with the percentage of women who have secondary and above education in the community. This percentage in communities with low level of women's education is highest in Cameroon (11.1 per cent). Comparatively, the corresponding figure in communities with high level of women's education is highest in Malawi (8.2 per cent).

Finally, the percentage of under-five deaths in communities with low level of poverty varies from 4.1 per cent in Senegal to 8.5 per cent in Malawi. By contrast, the corresponding distribution in communities with high level of poverty varies from 6.7 per cent in Senegal to 11.3 per cent in Burkina Faso.

**Figure 4.1. Age pattern of risk of death**




## 4.2. Age pattern of risk of death and household environmental health hazards

Figure 4.1 depicts the age pattern of risk of death among under-five children for all countries included in the study. The figure presents the risk of death in per cent for children in the age categories 0, 1-5, 6-11, 12-23 and 24-59 months. The risk of death represents the conditional probability expressed in per cent that a child who survives until the beginning of a given age interval will die in the same age interval. The same information can also be found in the last column of Table 4.2. The figure suggests that the risk of death is highest during the first month after birth and it declines on wards but with slight to moderate increase towards the end for many countries. Specifically, the risk of death during the first month after birth varies from 2.4 per cent in Niger to 3.6 per cent in Ethiopia. Comparatively, the corresponding risk in the 24-59 months interval varies from 0.7 per cent in Rwanda to 3.1 per cent in Niger. The figure also suggests that pattern of risk is remarkably different for three of the West African countries that are included in the study: Burkina Faso, Guinea, and Niger. In these countries, the risk declines from a high level during the first month after birth to a low level during 1-5 months, and rises onwards. In particular, in these countries, the risks of death in 24-59 months interval are 2.5, 2.6, 2.2 and 3.1 per cents, respectively. By contrast, the risk for the same age category is substantially low for other countries in the study.

In addition, Table 4.2 also provides information on the age pattern of risk of death by the level of household environmental health hazards. To aid visualization and understanding, the same information is also presented on graphs that are attached under Appendix 2. Generally, the graphs reveal that the age pattern of the risk of death among children who are potentially exposed to high levels of health hazards is above the corresponding graphs for children with low and medium levels of exposure. Moreover, a closer examination of the pattern of these graphs indicates that the risk gap between children with high exposure and those with low exposure depends on the age group in some countries, including Burkina Faso, Cameroon, Guinea, Malawi and Niger. In particular, the risk gap is considerably wide for the 24-59 months age group compared to the gap for the youngest age group (0 month). For instance, the risk in the first month after birth is 2.3 per cent in households with low health risk environments compared to 3.1 per cent in high risk environments in Burkina Faso. Comparatively the corresponding risks for the same country in the 24-59 months interval are 1.1 and 3.6, respectively. This finding implies that the effect of environmental health hazards is relatively important during late childhood. In the next sections, further analysis using multilevel models seeks to assess the significance of the interaction of age with the level of health hazards.

**Table 4.2. Age pattern of risk of death by household environmental health hazards**

| Country | Age (months) | Household environmental health hazards | | | Over all |
|---|---|---|---|---|---|
| | | Low | Medium | High | |
| **Burkina Faso** | 0 | 2.33 | 2.61 | 3.07 | 2.73 |
| | 1-5 | 1.18 | 1.28 | 1.95 | 1.54 |
| | 6-11 | 1.31 | 1.97 | 2.63 | 2.07 |
| | 12-23 | 1.34 | 2.22 | 2.44 | 2.08 |
| | 24-59 | 1.06 | 2.34 | 3.61 | 2.52 |
| **Burundi** | 0 | 2.68 | 2.92 | 3.39 | 3.04 |
| | 1-5 | 0.80 | 1.04 | 1.75 | 1.24 |
| | 6-11 | 0.75 | 1.52 | 1.71 | 1.42 |
| | 12-23 | 0.40 | 1.30 | 1.08 | 1.02 |
| | 24-59 | 0.44 | 1.52 | 1.44 | 1.25 |
| **Cameroon** | 0 | 2.50 | 2.95 | 3.19 | 2.97 |
| | 1-5 | 1.00 | 0.98 | 1.63 | 1.24 |
| | 6-11 | 1.38 | 1.70 | 1.92 | 1.72 |
| | 12-23 | 1.01 | 1.70 | 3.28 | 2.19 |
| | 24-59 | 0.75 | 2.23 | 3.95 | 2.63 |
| **Cote d'Ivoire** | 0 | 3.57 | 3.54 | 3.68 | 3.60 |
| | 1-5 | 1.54 | 1.79 | 1.77 | 1.71 |
| | 6-11 | 0.87 | 1.22 | 1.55 | 1.24 |
| | 12-23 | 0.45 | 1.57 | 2.11 | 1.47 |
| | 24-59 | 1.61 | 2.20 | 1.43 | 1.77 |
| **Ethiopia** | 0 | 3.00 | 3.52 | 4.07 | 3.63 |
| | 1-5 | 1.09 | 1.22 | 1.48 | 1.29 |
| | 6-11 | 0.85 | 0.51 | 1.42 | 0.88 |
| | 12-23 | 1.07 | 0.68 | 1.08 | 0.88 |
| | 24-59 | 0.49 | 1.17 | 1.57 | 1.20 |
| **Gabon** | 0 | 2.56 | 3.03 | 1.95 | 2.61 |
| | 1-5 | 0.31 | 0.69 | 0.68 | 0.51 |
| | 6-11 | 0.84 | 1.02 | 1.19 | 0.97 |
| | 12-23 | 1.07 | 0.46 | 0.79 | 0.80 |
| | 24-59 | 1.84 | 0.79 | 2.27 | 1.54 |

**Table 4.2.Continued**

| Country | Age (months) | Household environmental health hazards | | | Over all |
|---|---|---|---|---|---|
| | | Low | Medium | High | |
| **Guinea** | 0 | 2.72 | 3.05 | 4.03 | 3.28 |
| | 1-5 | 0.88 | 1.43 | 1.95 | 1.44 |
| | 6-11 | 0.78 | 2.23 | 2.39 | 1.85 |
| | 12-23 | 1.01 | 2.08 | 2.33 | 1.84 |
| | 24-59 | 0.82 | 2.83 | 2.82 | 2.21 |
| **Malawi** | 0 | 3.00 | 3.05 | 3.35 | 3.13 |
| | 1-5 | 1.78 | 1.52 | 1.25 | 1.52 |
| | 6-11 | 2.17 | 2.16 | 1.52 | 1.95 |
| | 12-23 | 1.09 | 2.03 | 1.78 | 1.61 |
| | 24-59 | 1.18 | 2.32 | 2.36 | 1.93 |
| **Niger** | 0 | 2.02 | 2.57 | 2.47 | 2.37 |
| | 1-5 | 0.79 | 1.11 | 1.23 | 1.12 |
| | 6-11 | 1.08 | 1.62 | 1.63 | 1.49 |
| | 12-23 | 1.70 | 1.83 | 2.45 | 2.22 |
| | 24-59 | 1.61 | 2.50 | 3.62 | 3.06 |
| **Rwanda** | 0 | 1.32 | 2.62 | 3.06 | 2.67 |
| | 1-5 | 1.39 | 1.14 | 0.93 | 1.06 |
| | 6-11 | 0.65 | 0.79 | 1.43 | 1.11 |
| | 12-23 | 0.63 | 0.44 | 1.23 | 0.90 |
| | 24-59 | 0.38 | 0.46 | 0.90 | 0.69 |
| **Senegal** | 0 | 2.54 | 2.44 | 3.49 | 2.75 |
| | 1-5 | 0.86 | 0.94 | 1.28 | 0.99 |
| | 6-11 | 0.35 | 0.79 | 0.61 | 0.54 |
| | 12-23 | 0.45 | 0.83 | 0.87 | 0.67 |
| | 24-59 | 0.47 | 0.90 | 1.49 | 0.84 |
| **Zimbabwe** | 0 | 2.40 | 4.17 | 2.32 | 2.99 |
| | 1-5 | 1.24 | 1.84 | 1.39 | 1.50 |
| | 6-11 | 1.19 | 0.80 | 1.23 | 1.07 |
| | 12-23 | 0.87 | 1.40 | 1.36 | 1.22 |
| | 24-59 | 1.25 | 0.92 | 1.74 | 1.31 |

## 4.3. Fitted models

This section presents the results from fitting a two-level random intercept discrete-time hazard models. Before directly presenting the results on fitted models, it is worth to note that the study has considered the possibility of fitting a three-level discrete-time hazard model with children, households and communities representing first, second and third levels, respectively. However, the average number of births and deaths per household are too small to fit sensible models. For this reason, the study adopts a two-level model with children, first-level, nested within communities (second-levels).

Five models are fitted for each country: Model0, model1, model2, model3 and model4. Model0 represents the null model (i.e. with no covariate). Model1 includes age as the only covariate. Model2 has the index of household environmental health hazards in addition to age. Model3 includes other individual, household and community-level covariates in addition to the covariates in model2. Model4 includes all covariates in model3 but it considers separate effects of the index of household environmental health hazards for each age group. These fitted models serve several purposes. Model0 and Model1 are used to assess the effect of clustering and the age dependence of the hazard function. Model2 helps to examine the importance of household environmental health hazards alone. Model3 is used to assess the effect of household environmental health hazards after controlling for the effects of all other covariates. Finally, model4 enables one to assess the significance of interaction between the level of health hazards and age. Results from fitting these models are presented under Table 4.4. These results are commented in the following sub-sections.

**Table 4.3. Intra-class correlations for fitted models**

| | Model0 | | | Model1 | | | Model2 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Countries** | **ICC(%)** | **95%-CI** | | **ICC(%)** | **95%-CI** | | **ICC(%)** | **95%-CI** | |
| **Burkina Faso** | 5.72[a] | 4.02 | 8.08 | 5.71[a] | 4.01 | 8.07 | 4.04[a] | 2.56 | 6.32 |
| **Burundi** | 5.44[a] | 2.69 | 10.68 | 5.05[a] | 2.39 | 10.37 | 3.73[b] | 1.42 | 9.46 |
| **Cameroon** | 6.83[a] | 4.62 | 9.97 | 6.82[a] | 4.62 | 9.97 | 5.31[a] | 3.32 | 8.39 |
| **Cote de ivory** | 7.44[a] | 4.83 | 11.31 | 7.17[a] | 4.6 | 11.01 | 6.74[a] | 4.22 | 10.6 |
| **Ethiopia** | 4.71[a] | 2.66 | 8.2 | 4.29[a] | 2.31 | 7.82 | 4.04[a] | 2.1 | 7.62 |
| **Gabon** | 2.69 | 0.46 | 14.18 | 2.44 | 0.36 | 14.98 | 2.07 | 0.21 | 17.4 |
| **Guinea** | 6.58[a] | 4.03 | 10.57 | 6.40[a] | 3.88 | 10.38 | 4.68[a] | 2.53 | 8.51 |
| **Malawi** | 4.38[a] | 2.89 | 6.59 | 4.19[a] | 2.72 | 6.39 | 4.19[a] | 2.72 | 6.4 |
| **Niger** | 9.11[a] | 6.61 | 12.42 | 9.28[a] | 6.76 | 12.62 | 7.66[a] | 5.36 | 10.83 |
| **Rwanda** | 4.92[a] | 2.19 | 10.68 | 4.35[a] | 1.76 | 10.36 | 3.5[b] | 1.17 | 10.05 |
| **Senegal** | 5.59[a] | 3.3 | 9.33 | 5.29[a] | 3.05 | 9.02 | 4.41[a] | 2.32 | 8.22 |
| **Zimbabwe** | 5.24[a] | 2.06 | 12.68 | 4.81[b] | 1.77 | 12.42 | 4.86[b] | 1.8 | 12.48 |

Significance c: P<0.1; b: P <0.05 ; a: P<0.01

**Table 4.3. Continued**

| Countries | Model3 | | | Model4 | | |
|---|---|---|---|---|---|---|
| | ICC(%) | 95%-CI | | ICC(%) | 95%-CI | |
| **Burkina Faso** | 2.72[a] | 1.46 | 5.02 | 2.73[a] | 1.47 | 5.03 |
| **Burundi** | 3.30[b] | 1.1 | 9.5 | 3.35[b] | 1.13 | 9.5 |
| **Cameroon** | 3.91[a] | 2.13 | 7.06 | 3.96[a] | 2.17 | 7.1 |
| **Cote de ivory** | 5.00[a] | 2.73 | 8.97 | 5.00[a] | 2.74 | 8.98 |
| **Ethiopia** | 3.39[a] | 1.58 | 7.12 | 3.38[a] | 1.57 | 7.11 |
| **Gabon** | 0.47 | 0 | 98.58 | 0.5 | 0 | 97.55 |
| **Guinea** | 3.75[a] | 1.8 | 7.65 | 3.76[a] | 1.81 | 7.66 |
| **Malawi** | 3.69[a] | 2.28 | 5.91 | 3.69[a] | 2.29 | 5.91 |
| **Niger** | 7.33[a] | 5.07 | 10.49 | 7.34[a] | 5.08 | 10.5 |
| **Rwanda** | 2.88[c] | 0.76 | 10.29 | 2.86[c] | 0.75 | 10.29 |
| **Senegal** | 3.34[a] | 1.47 | 7.42 | 3.33[a] | 1.46 | 7.4 |
| **Zimbabwe** | 2.3 | 0.29 | 16.19 | 2.32 | 0.29 | 16.08 |

Significance c:<0.1; b: <0.05 ; a:<0.01

### 4.3.1. Assessing death clustering and age dependence of the hazard function

Before fitting more complex models, it is important to assess the importance of clustering effects on under-five mortality. Table 4.3 presents the Intra-Class Correlation (ICC) in per cent for all fitted models. This coefficient measures the extent of clustering of deaths in certain communities and can also be viewed as a measure of heterogeneity among communities in under-five mortality. A large value of this coefficient indicates high heterogeneity in under-five mortality among communities. In particular, this sub-section refers the results under model0 and model1 in Table 4.3 . The result indicates that the ICCs of both models are highly significant for all countries, except for Gabon. This result suggests that there are heterogeneities in under-five mortality among communities within countries. This evidence justifies the use of multilevel approach in modelling the covariates of under-five mortality in that it accounts for the effect of clustering of the outcome variable when it is present.

The percentage of total variability in under-five mortality accounted by community differences varies from 2.69 per cent in Gabon to 9.11 per cent in Niger under model0 and from 2.44 per cent in Gabon to 9.28 per cent in Niger under model1. The result under model1 in Table 4.4 also confirms the age dependence of the hazard function, which is noted in section 4.2 in that the risk of death is significantly associated with the age of the child in all countries that are included in the study. Thus, the result under the two models establishes the importance of including community-level random effect and age in further models. The next sub-sections present results under other models.

**Table 4.4. Fitted models**

| | Burkina Faso | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model1 | | Model2 | | Model3 | | Model4 | |
| Covariates | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI |
| **Health hazard level** | | | 1.18[a] | (1.13,1.24) | 1.05 | (0.98,1.13) | | |
| **Age & Health hazard Interaction** | | | | | | | | |
| Age0*Health hazard | | | | | | | 0.98 | (0.90,1.08) |
| Age1-5*Health hazard | | | | | | | 1.04 | (0.92,1.17) |
| Age6-11*Health hazard | | | | | | | 1.08 | (0.97,1.21) |
| Age 12-23*Health hazard | | | | | | | 1.06 | (0.94,1.19) |
| Age 24-59*Health hazard | | | | | | | 1.18[b] | (1.04,1.34) |
| **Age(months)** | | | | | | | | |
| 0 | 1.08 | (0.91,1.29) | 1.08 | (0.91,1.29) | 1.09 | (0.92,1.30) | 1.24[b] | (1.02,1.51) |
| 1-5 | 0.59[a] | (0.48,0.71) | 0.59[a] | (0.48,0.71) | 0.59a | (0.49,0.72) | 0.65[a] | (0.52,0.81) |
| 6-11 | 0.80[b] | (0.67,0.96) | 0.8[b] | (0.67,0.97) | 0.81[b] | (0.67,0.97) | 0.87 | (0.70,1.08) |
| 12-23 | 0.78[b] | (0.65,0.95) | 0.78[b] | (0.65,0.95) | 0.79[b] | (0.65,0.96) | 0.86 | (0.68,1.07) |
| 24-59 (R) | | | | | | | | |
| **Sex** | | | | | | | | |
| Male | | | | | 1.15[b] | (1.03,1.29) | 1.15[b] | (1.03,1.29) |
| Female (R) | | | | | | | | |
| **Birth order and interval** | | | | | | | | |
| 1st (R) | | | | | | | | |
| 2nd & >=2 years | | | | | 0.77[b] | (0.61,0.97) | 0.77[b] | (0.61,0.97) |
| 2nd & < 2 years | | | | | 1.62[a] | (1.17,2.24) | 1.62[a] | (1.17,2.24) |
| 3+ & >= 2 years | | | | | 0.95 | (0.78,1.17) | 0.95 | (0.78,1.17) |
| 3+& <2 years | | | | | 2.08[a] | (1.64,2.64) | 2.08[a] | (1.64,2.64) |
| **Mother's age at birth** | | | | | | | | |
| Less than 20 years | | | | | 1.33[a] | (1.09,1.63) | 1.33[a] | (1.09,1.63) |
| 20-34 (R) | | | | | | | | |
| 35 or more years | | | | | 1.00 | (0.85,1.17) | 1.00 | (0.85,1.17) |
| **Mother's education** | | | | | | | | |
| No education | | | | | 1.30 | (0.90,1.87) | 1.31 | (0.91,1.88) |
| Primary | | | | | 1.06 | (0.72,1.57) | 1.07 | (0.72,1.58) |
| Secondary and above (R) | | | | | | | | |
| **Mother's HIV status** | | | | | | | | |
| Negative (R) | | | | | | | | |
| Positive | | | | | 2.06[b] | (1.11,3.83) | 2.05[b] | (1.10,3.81) |
| No test | | | | | 0.90[c] | (0.81,1.01) | 0.90[c] | (0.81,1.01) |
| **Household wealth** | | | | | | | | |
| Poor | | | | | 0.98 | (0.79,1.20) | 0.98 | (0.79,1.20) |
| Middle | | | | | 0.97 | (0.81,1.17) | 0.97 | (0.81,1.17) |
| Rich (R) | | | | | | | | |
| **Residence** | | | | | | | | |
| Urban (R) | | | | | | | | |
| Rural | | | | | 0.89 | (0.70,1.13) | 0.89 | (0.70,1.14) |
| **Community-level of health service** | | | | | 0.95[b] | (0.90,0.99) | 0.95[b] | (0.90,0.99) |
| **Community-level of mothers' education** | | | | | 0.81 | (0.36,1.80) | 0.8 | (0.36,1.79) |
| **Community-level of poverty** | | | | | 1.69[a] | (1.23,2.32) | 1.69[a] | (1.23,2.32) |
| **Random effects** | | | | | | | | |
| Community-level stdv | 0.45[a] | (0.37,0.54) | 0.37[a] | (0.29,0.47) | 0.30[a] | (0.22,0.42) | 0.30[a] | (0.22,0.42) |

Significance c: P<0.1; b: P <0.05 ; a: P<0.01; R: Reference category

**Table 4.4. Continued**

| Covariates | Burundi | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model1 | | Model2 | | Model3 | | Model4 | |
| | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI |
| **Health hazard level** | | | 1.22[a] | (1.13,1.32) | 1.11[b] | (1.00,1.23) | | |
| **Age & Health Hazard Interaction** | | | | | | | | |
| Age0*Health hazard | | | | | | | 1.00 | (0.87,1.13) |
| Age1-5*Health hazard | | | | | | | 1.19[c] | (0.97,1.45) |
| Age6-11*Health hazard | | | | | | | 1.20[c] | (0.99,1.45) |
| Age 12-23*Health hazard | | | | | | | 1.24 | (0.96,1.61) |
| Age 24-59*Health hazard | | | | | | | 1.30[a] | (0.99,1.70) |
| **Age(months)** | | | | | | | | |
| 0 | 2.47[a] | (1.80,3.37) | 2.47[a] | (1.80,3.37) | 2.47[a] | (1.80,3.38) | 2.80[a] | (1.96,4.00) |
| 1-5 | 1.01 | (0.71,1.44) | 1.01 | (0.71,1.43) | 1.01 | (0.71,1.44) | 1.06 | (0.71,1.59) |
| 6-11 | 1.25 | (0.89,1.77) | 1.25 | (0.88,1.77) | 1.26 | (0.89,1.78) | 1.32 | (0.89,1.96) |
| 12-23 | 0.76 | (0.51,1.12) | 0.76 | (0.51,1.12) | 0.76 | (0.51,1.12) | 0.78 | (0.49,1.22) |
| 24-59 (R) | | | | | | | | |
| **Sex** | | | | | | | | |
| Male | | | | | 1.16 | (0.97,1.39) | 1.16 | (0.97,1.39) |
| Female (R) | | | | | | | | |
| **Birth order and interval** | | | | | | | | |
| 1st (R) | | | | | | | | |
| 2nd & >=2 years | | | | | 0.66[b] | (0.47,0.92) | 0.66[b] | (0.47,0.92) |
| 2nd & < 2 years | | | | | 0.83 | (0.53,1.28) | 0.82 | (0.53,1.27) |
| 3+ & >= 2 years | | | | | 0.56[a] | (0.43,0.74) | 0.56[a] | (0.43,0.74) |
| 3+& <2 years | | | | | 1.26 | (0.92,1.71) | 1.26 | (0.92,1.71) |
| **Mother's age at birth** | | | | | | | | |
| Less than 20 years | | | | | 1.06 | (0.77,1.46) | 1.06 | (0.77,1.46) |
| 20-34 (R) | | | | | | | | |
| 35 or more years | | | | | 1.20 | (0.93,1.55) | 1.20 | (0.93,1.54) |
| **Mother's education** | | | | | | | | |
| No education | | | | | 2.40[a] | (1.38,4.18) | 2.44[a] | (1.40,4.27) |
| Primary | | | | | 1.95[b] | (1.13,3.36) | 1.99[b] | (1.15,3.43) |
| Secondary and above (R) | | | | | | | | |
| **Mother's HIV status** | | | | | | | | |
| Negative (R) | | | | | | | | |
| Positive | | | | | 1.59 | (0.77,3.29) | 1.59 | (0.77,3.30) |
| No test | | | | | 1.03 | (0.86,1.24) | 1.03 | (0.86,1.24) |
| **Household wealth** | | | | | | | | |
| Poor | | | | | 1.07 | (0.83,1.39) | 1.07 | (0.83,1.38) |
| Middle | | | | | 0.96 | (0.73,1.27) | 0.96 | (0.73,1.27) |
| Rich (R) | | | | | | | | |
| **Residence** | | | | | | | | |
| Urban (R) | | | | | | | | |
| Rural | | | | | 0.73 | (0.49,1.10) | 0.74 | (0.49,1.11) |
| **Community-level of health service** | | | | | 0.89[b] | (0.81,0.98) | 0.89[b] | (0.81,0.98) |
| **Community-level of mothers' education** | | | | | 0.87 | (0.28,2.68) | 0.86 | (0.28,2.65) |
| **Community-level of poverty** | | | | | 1.27 | (0.68,2.37) | 1.27 | (0.68,2.37) |
| **Random effects** | | | | | | | | |
| Community-level stdv | 0.42[a] | (0.28,0.62) | 0.36[b] | (0.22,0.59) | 0.34[b] | (0.19,0.59) | 0.34[b] | (0.19,0.59) |

Significance c: P<0.1; b: P <0.05 ; a: P<0.01; R: Reference category

**Table 4.4. Continued**

| Covariates | Cameroon | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model1 | | Model2 | | Model3 | | Model4 | |
| | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI |
| **Health hazard level** | | | 1.14[a] | (1.09,1.19) | 1.00 | (0.93,1.07) | | |
| **Age & Health Hazard Interaction** | | | | | | | | |
| Age0*Health hazard | | | | | | | 0.89[a] | (0.81,0.97) |
| Age1-5*Health hazard | | | | | | | 1.01 | (0.89,1.14) |
| Age6-11*Health hazard | | | | | | | 0.96 | (0.86,1.07) |
| Age 12-23*Health hazard | | | | | | | 1.12[c] | (1.00,1.25) |
| Age 24-59*Health hazard | | | | | | | 1.19[a] | (1.05,1.34) |
| **Age(months)** | | | | | | | | |
| 0 | 1.18[c] | (0.97,1.44) | 1.19[c] | (0.98,1.44) | 1.19[c] | (0.98,1.45) | 1.48[a] | (1.17,1.86) |
| 1-5 | 0.48[a] | (0.38,0.60) | 0.48[a] | (0.38,0.61) | 0.48[a] | (0.38,0.61) | 0.56[a] | (0.42,0.73) |
| 6-11 | 0.69[a] | (0.56,0.87) | 0.70[a] | (0.56,0.87) | 0.70[a] | (0.56,0.87) | 0.83 | (0.64,1.08) |
| 12-23 | 0.89 | (0.72,1.11) | 0.89 | (0.72,1.11) | 0.89 | (0.72,1.11) | 0.95 | (0.73,1.23) |
| 24-59 (R) | | | | | | | | |
| **Sex** | | | | | | | | |
| Male | | | | | 1.12[c] | (0.98,1.27) | 1.12[c] | (0.98,1.27) |
| Female (R) | | | | | | | | |
| **Birth order and interval** | | | | | | | | |
| 1st (R) | | | | | | | | |
| 2nd & >=2 years | | | | | 0.82 | (0.64,1.05) | 0.82 | (0.64,1.05) |
| 2nd & < 2 years | | | | | 1.49[b] | (1.09,2.05) | 1.49[b] | (1.09,2.04) |
| 3+ & >= 2 years | | | | | 0.92 | (0.74,1.14) | 0.92 | (0.74,1.15) |
| 3+& <2 years | | | | | 1.63[a] | (1.29,2.07) | 1.63[a] | (1.28,2.07) |
| **Mother's age at birth** | | | | | | | | |
| Less than 20 years | | | | | 1.12 | (0.92,1.37) | 1.12 | (0.92,1.37) |
| 20-34 (R) | | | | | | | | |
| 35 or more years | | | | | 0.98 | (0.80,1.21) | 0.98 | (0.80,1.21) |
| **Mother's education** | | | | | | | | |
| No education | | | | | 1.53[a] | (1.19,1.97) | 1.53[a] | (1.19,1.97) |
| Primary | | | | | 1.26[b] | (1.03,1.53) | 1.26[b] | (1.03,1.54) |
| Secondary and above (R) | | | | | | | | |
| **Mother's HIV status** | | | | | | | | |
| Negative (R) | | | | | | | | |
| Positive | | | | | 2.79[a] | (2.02,3.87) | 2.80[a] | (2.02,3.88) |
| No test | | | | | 1.07 | (0.94,1.23) | 1.07 | (0.94,1.23) |
| **Household wealth** | | | | | | | | |
| Poor | | | | | 1.31 | (0.93,1.86) | 1.33 | (0.94,1.87) |
| Middle | | | | | 1.04 | (0.81,1.32) | 1.05 | (0.82,1.34) |
| Rich (R) | | | | | | | | |
| **Residence** | | | | | | | | |
| Urban (R) | | | | | | | | |
| Rural | | | | | 0.92 | (0.70,1.23) | 0.93 | (0.70,1.24) |
| **Community-level of health service** | | | | | 0.98 | (0.92,1.05) | 0.98 | (0.92,1.05) |
| **Community-level of mothers' education** | | | | | 0.57[b] | (0.35,0.93) | 0.57[b] | (0.35,0.92) |
| **Community-level of poverty** | | | | | 0.82 | (0.51,1.31) | 0.81 | (0.50,1.29) |
| **Random effects** | | | | | | | | |
| Community-level stdv | 0.49[a] | (0.40,0.60) | 0.43[a] | (0.34,0.55) | 0.37[a] | (0.27,0.50) | 0.37[a] | (0.27,0.50) |

Significance c: P<0.1; b: P <0.05 ; a: P<0.01; R: Reference category

**Table 4.4.Continued**

| Covariates | Cote d'Ivoire | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model1 | | Model2 | | Model3 | | Model4 | |
| | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI |
| **Health hazard level** | | | 1.07[b] | (1.01,1.12) | 1.02 | (0.95,1.09) | | |
| **Age & Health Hazard Interaction** | | | | | | | | |
| Age0*Health hazard | | | | | | | 0.98 | (0.89,1.06) |
| Age1-5*Health hazard | | | | | | | 1.04 | (0.93,1.17) |
| Age6-11*Health hazard | | | | | | | 1.11 | (0.98,1.26) |
| Age 12-23*Health hazard | | | | | | | 1.11 | (0.98,1.26) |
| Age 24-59*Health hazard | | | | | | | 0.93 | (0.80,1.07) |
| **Age(months)** | | | | | | | | |
| 0 | 2.11[a] | (1.62,2.74) | 2.11[a] | (1.62,2.74) | 2.10[a] | (1.61,2.73) | 2.06[a] | (1.58,2.69) |
| 1-5 | 0.96 | (0.71,1.28) | .96 | (0.71,1.29) | 0.96 | (0.71,1.28) | 0.91 | (0.68,1.23) |
| 6-11 | 0.82 | (0.60,1.11) | 0.82 | (0.60,1.11) | 0.81 | (0.60,1.11) | 0.75[c] | (0.54,1.03) |
| 12-23 | 0.96 | (0.71,1.31) | .96 | (0.71,1.31) | 0.96 | (0.70,1.31) | 0.88 | (0.64,1.22) |
| 24-59 (R) | | | | | | | | |
| **Sex** | | | | | | | | |
| Male | | | | | 1.64[a] | (1.40,1.92) | 1.64[a] | (1.40,1.92) |
| Female (R) | | | | | | | | |
| **Birth order and interval** | | | | | | | | |
| 1st (R) | | | | | | | | |
| 2nd & >=2 years | | | | | 0.73[b] | (0.54,0.98) | 0.72[b] | (0.54,0.97) |
| 2nd & < 2 years | | | | | 0.97 | (0.59,1.61) | 0.97 | (0.59,1.61) |
| 3+ & >= 2 years | | | | | 0.90 | (0.69,1.17) | 0.9 | (0.69,1.17) |
| 3+& <2 years | | | | | 1.92[a] | (1.42,2.58) | 1.92[a] | (1.42,2.58) |
| **Mother's age at birth** | | | | | | | | |
| Less than 20 years | | | | | 1.09 | (0.84,1.41) | 1.09 | (0.84,1.41) |
| 20-34 (R) | | | | | | | | |
| 35 or more years | | | | | 1.22[c] | (0.98,1.52) | 1.23[c] | (0.98,1.53) |
| **Mother's education** | | | | | | | | |
| No education | | | | | 1.07 | (0.77,1.51) | 1.08 | (0.77,1.51) |
| Primary | | | | | 1.09 | (0.76,1.55) | 1.09 | (0.77,1.55) |
| Secondary and above (R) | | | | | | | | |
| **Mother's HIV status** | | | | | | | | |
| Negative (R) | | | | | | | | |
| Positive | | | | | 1.87[b] | (1.12,3.12) | 1.86[b] | (1.11,3.12) |
| No test | | | | | 1.07 | (0.91,1.25) | 1.07 | (0.91,1.25) |
| **Household wealth** | | | | | | | | |
| Poor | | | | | 1.04 | (0.77,1.39) | 1.04 | (0.77,1.40) |
| Middle | | | | | 0.86 | (0.66,1.12) | 0.86 | (0.67,1.12) |
| Rich (R) | | | | | | | | |
| **Residence** | | | | | | | | |
| Urban (R) | | | | | | | | |
| Rural | | | | | 1.24 | (0.77,2.01) | 1.24 | (0.77,2.01) |
| **Community-level of health service** | | | | | 0.92[b] | (0.86,0.98) | 0.92[b] | (0.86,0.98) |
| **Community-level of mothers' education** | | | | | 0.91 | (0.37,2.25) | 0.91 | (0.37,2.24) |
| **Community-level of poverty** | | | | | 0.64 | (0.35,1.17) | 0.64 | (0.35,1.18) |
| **Random effects** | | | | | | | | |
| Community-level stdv | 0.5[a] | (0.40,0.64) | 0.49[a] | (0.38,0.62) | 0.42[a] | (0.30,0.57) | 0.42[a] | (0.30,0.57) |

Significance c: P<0.1; b: P <0.05 ; a: P<0.01; R: Reference category

**Table 4.4. Continued**

| Covariates | Ethiopia | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model1 | | Model2 | | Model3 | | Model4 | |
| | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI |
| **Health hazard level** | | | 1.09[a] | (1.02,1.16) | 1.02 | (0.93,1.13) | | |
| **Age & Health Hazard Interaction** | | | | | | | | |
| Age0*Health hazard | | | | | | | 1.01 | (0.90,1.14) |
| Age1-5*Health hazard | | | | | | | 1.04 | (0.88,1.23) |
| Age6-11*Health hazard | | | | | | | 1.14 | (0.93,1.41) |
| Age 12-23*Health hazard | | | | | | | 0.89 | (0.74,1.06) |
| Age 24-59*Health hazard | | | | | | | 1.11 | (0.90,1.37) |
| **Age(months)** | | | | | | | | |
| 0 | 2.40a | (1.92,3.01) | 2.40[a] | (1.92,3.01) | 2.45[a] | (1.96,3.08) | 2.65[a] | (1.98,3.54) |
| 1-5 | 0.91 | (0.70,1.18) | 0.91 | (0.70,1.18) | 0.93 | (0.71,1.20) | 0.98 | (0.70,1.36) |
| 6-11 | 0.73[b] | (0.55,0.96) | 0.73[b] | (0.55,0.96) | 0.74[b] | (0.56,0.98) | 0.72[c] | (0.49,1.04) |
| 12-23 | 0.67[a] | (0.50,0.90) | 0.67[a] | (0.50,0.90) | 0.68[a] | (0.50,0.91) | 0.8 | (0.56,1.13) |
| 24-59 (R) | | | | | | | | |
| **Sex** | | | | | | | | |
| Male | | | | | 1.18[b] | (1.03,1.36) | 1.18[b] | (1.03,1.36) |
| Female (R) | | | | | | | | |
| **Birth order and interval** | | | | | | | | |
| 1st (R) | | | | | | | | |
| 2nd & >=2 years | | | | | 0.77[c] | (0.58,1.02) | 0.77[c] | (0.58,1.02) |
| 2nd & < 2 years | | | | | 1.55[a] | (1.13,2.13) | 1.55[a] | (1.13,2.13) |
| 3+ & >= 2 years | | | | | 0.84 | (0.66,1.08) | 0.84 | (0.66,1.08) |
| 3+& <2 years | | | | | 1.78[a] | (1.38,2.29) | 1.78[a] | (1.38,2.29) |
| **Mother's age at birth** | | | | | | | | |
| Less than 20 years | | | | | 1.60[a] | (1.28,2.00) | 1.60[a] | (1.28,2.00) |
| 20-34 (R) | | | | | | | | |
| 35 or more years | | | | | 1.25[b] | (1.01,1.54) | 1.25[b] | (1.01,1.54) |
| **Mother's education** | | | | | | | | |
| No education | | | | | 1.53 | (0.88,2.67) | 1.54 | (0.88,2.69) |
| Primary | | | | | 1.51 | (0.87,2.62) | 1.52 | (0.87,2.63) |
| Secondary and above (R) | | | | | | | | |
| **Mother's HIV status** | | | | | | | | |
| Negative (R) | | | | | | | | |
| Positive | | | | | 1.90[b] | (1.06,3.38) | 1.90[b] | (1.06,3.38) |
| No test | | | | | 0.98 | (0.68,1.42) | 0.98 | (0.68,1.42) |
| **Household wealth** | | | | | | | | |
| Poor | | | | | 1.13 | (0.89,1.45) | 1.13 | (0.89,1.44) |
| Middle | | | | | 1.08 | (0.84,1.38) | 1.08 | (0.84,1.38) |
| Rich (R) | | | | | | | | |
| **Residence** | | | | | | | | |
| Urban (R) | | | | | | | | |
| Rural | | | | | 0.77 | (0.55,1.09) | 0.77 | (0.55,1.09) |
| **Community-level of health service** | | | | | 0.97 | (0.88,1.06) | 0.96 | (0.88,1.06) |
| **Community-level of mothers' education** | | | | | 0.63 | (0.18,2.17) | 0.62 | (0.18,2.15) |
| **Community-level of poverty** | | | | | 1.03 | (0.70,1.50) | 1.02 | (0.70,1.49) |
| **Random effects** | | | | | | | | |
| Community-level stdv | 0.38[a] | (0.28,0.53) | 0.37[a] | (0.27,0.52) | 0.34[a] | (0.23,0.50) | 0.34[a] | (0.23,0.50) |

Significance c: P<0.1; b: P <0.05 ; a: P<0.01; R: Reference category

**Table 4.4. Continued**

| Covariates | Gabon | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model1 | | Model2 | | Model3 | | Model4 | |
| | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI |
| **Health hazard level** | | | 1.05 | (0.98,1.13) | 1.01 | (0.91,1.12) | | |
| **Age & Health Hazard Interaction** | | | | | | | | |
| Age0*Health hazard | | | | | | | 0.92 | (0.80,1.05) |
| Age1-5*Health hazard | | | | | | | 1.08 | (0.89,1.31) |
| Age6-11*Health hazard | | | | | | | 1.04 | (0.87,1.24) |
| Age 12-23*Health hazard | | | | | | | 1.02 | (0.83,1.25) |
| Age 24-59*Health hazard | | | | | | | 1.16 | (0.97,1.38) |
| **Age(months)** | | | | | | | | |
| 0 | 1.56[a] | (1.12,2.17) | 1.56[a] | (1.12,2.17) | 1.54[a] | (1.11,2.15) | 1.63[a] | (1.15,2.30) |
| 1-5 | 0.48[a] | (0.32,0.73) | 0.48[a] | (0.32,0.73) | 0.48[a] | (0.32,0.73) | 0.49[a] | (0.32,0.76) |
| 6-11 | 0.69[c] | (0.46,1.02) | 0.69[c] | (0.46,1.02) | 0.68[c] | (0.46,1.01) | 0.71 | (0.47,1.07) |
| 12-23 | 0.56[a] | (0.36,0.86) | 0.56[a] | (0.36,0.86) | 0.55[a] | (0.36,0.85) | 0.58[b] | (0.37,0.91) |
| 24-59 (R) | | | | | | | | |
| **Sex** | | | | | | | | |
| Male | | | | | 1.21[c] | (0.97,1.51) | 1.21[c] | (0.97,1.51) |
| Female (R) | | | | | | | | |
| **Birth order and interval** | | | | | | | | |
| 1st (R) | | | | | | | | |
| 2nd & >=2 years | | | | | 0.76 | (0.50,1.16) | 0.76 | (0.50,1.17) |
| 2nd & < 2 years | | | | | 2.32[a] | (1.49,3.61) | 2.32[a] | (1.49,3.61) |
| 3+ & >= 2 years | | | | | 0.60[b] | (0.41,0.90) | 0.61[b] | (0.41,0.90) |
| 3+& <2 years | | | | | 2.07[a] | (1.39,3.08) | 2.08[a] | (1.40,3.09) |
| **Mother's age at birth** | | | | | | | | |
| Less than 20 years | | | | | 1.04 | (0.74,1.46) | 1.04 | (0.74,1.46) |
| 20-34 (R) | | | | | | | | |
| 35 or more years | | | | | 1.56[a] | (1.14,2.15) | 1.56[a] | (1.13,2.14) |
| **Mother's education** | | | | | | | | |
| No education | | | | | 1.46[c] | (0.94,2.26) | 1.46[c] | (0.94,2.27) |
| Primary | | | | | 1.21 | (0.92,1.57) | 1.21 | (0.92,1.57) |
| Secondary and above (R) | | | | | | | | |
| **Mother's HIV status** | | | | | | | | |
| Negative (R) | | | | | | | | |
| Positive | | | | | 1.37 | (0.76,2.48) | 1.37 | (0.76,2.49) |
| No test | | | | | 1.14 | (0.90,1.45) | 1.14 | (0.90,1.45) |
| **Household wealth** | | | | | | | | |
| Poor | | | | | 0.97 | (0.64,1.45) | 0.98 | (0.65,1.47) |
| Middle | | | | | 1.05 | (0.69,1.60) | 1.05 | (0.69,1.61) |
| Rich (R) | | | | | | | | |
| **Residence** | | | | | | | | |
| Urban (R) | | | | | | | | |
| Rural | | | | | 1.02 | (0.74,1.40) | 1.02 | (0.74,1.41) |
| **Community-level of health service** | | | | | 0.93[c] | (0.85,1.01) | 0.93 | (0.85,1.01) |
| **Community-level of mothers' education** | | | | | 1.64 | (0.74,3.64) | 1.64 | (0.74,3.65) |
| **Community-level of poverty** | | | | | 1.11 | (0.54,2.27) | 1.13 | (0.55,2.31) |
| **Random effects** | | | | | | | | |
| Community-level stdv | 0.29 | (0.11,0.76) | 0.26 | (0.08,0.83) | 0.12 | (0.0,15.10) | 0.13 | (0.0,11.44) |

Significance c: P<0.1; b: P <0.05 ; a: P<0.01; R: Reference category

## Table 4.4. Continued

| Covariates | Guinea | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model1 | | Model2 | | Model3 | | Model4 | |
| | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI |
| **Health hazard level** | | | 1.15[a] | (1.09,1.21) | 1.04 | (0.92,1.19) | | |
| **Age & Health Hazard Interaction** | | | | | | | | |
| Age0*Health hazard | | | | | | | 0.96 | (0.83,1.11) |
| Age1-5*Health hazard | | | | | | | 1.09 | (0.91,1.30) |
| Age6-11*Health hazard | | | | | | | 1.09 | (0.92,1.29) |
| Age 12-23*Health hazard | | | | | | | 1.03 | (0.86,1.23) |
| Age 24-59*Health hazard | | | | | | | 1.20[c] | (0.99,1.44) |
| **Age(months)** | | | | | | | | |
| 0 | 1.46[a] | (1.14,1.88) | 1.46[a] | (1.14,1.88) | 1.47[a] | (1.14,1.90) | 1.69[a] | (1.27,2.24) |
| 1-5 | 0.59[a] | (0.44,0.79) | 0.59[a] | (0.44,0.79) | 0.60[a] | (0.44,0.80) | 0.64[a] | (0.46,0.89) |
| 6-11 | 0.80 | (0.60,1.07) | 0.81 | (0.60,1.07) | 0.81 | (0.61,1.08) | 0.87 | (0.63,1.20) |
| 12-23 | 0.77[c] | (0.57,1.04) | 0.77[c] | (0.57,1.04) | 0.78[c] | (0.58,1.05) | 0.86 | (0.62,1.20) |
| 24-59 (R) | | | | | | | | |
| **Sex** | | | | | | | | |
| Male | | | | | 1.17[c] | (0.99,1.38) | 1.17[c] | (0.99,1.38) |
| Female (R) | | | | | | | | |
| **Birth order and interval** | | | | | | | | |
| 1st (R) | | | | | | | | |
| 2nd & >=2 years | | | | | 0.74[b] | (0.55,1.01) | 0.75[c] | (0.55,1.01) |
| 2nd & < 2 years | | | | | 1.25 | (0.76,2.05) | 1.25 | (0.76,2.05) |
| 3+ & >= 2 years | | | | | 0.84 | (0.63,1.12) | 0.84 | (0.63,1.12) |
| 3+& <2 years | | | | | 1.52[b] | (1.08,2.13) | 1.52[b] | (1.08,2.14) |
| **Mother's age at birth** | | | | | | | | |
| Less than 20 years | | | | | 1.21 | (0.93,1.57) | 1.21 | (0.93,1.57) |
| 20-34 (R) | | | | | | | | |
| 35 or more years | | | | | 1.02 | (0.80,1.30) | 1.02 | (0.80,1.30) |
| **Mother's education** | | | | | | | | |
| No education | | | | | 1.64[b] | (1.09,2.47) | 1.64[b] | (1.09,2.47) |
| Primary | | | | | 1.63[b] | (1.04,2.55) | 1.63 | (1.04,2.55) |
| Secondary and above (R) | | | | | | | | |
| **Mother's HIV status** | | | | | | | | |
| Negative (R) | | | | | | | | |
| Positive | | | | | 2.27[b] | (1.17,4.41) | 2.27[b] | (1.17,4.41) |
| No test | | | | | 0.98 | (0.83,1.15) | 0.98 | (0.83,1.15) |
| **Household wealth** | | | | | | | | |
| Poor | | | | | 1.17 | (0.71,1.92) | 1.18 | (0.72,1.94) |
| Middle | | | | | 1.41[b] | (1.00,1.98) | 1.42[b] | (1.01,2.00) |
| Rich (R) | | | | | | | | |
| **Residence** | | | | | | | | |
| Urban (R) | | | | | | | | |
| Rural | | | | | 0.79 | (0.52,1.19) | 0.79 | (0.52,1.19) |
| **Community-level of health service** | | | | | 0.94 | (0.87,1.02) | 0.94 | (0.87,1.02) |
| **Community-level of mothers' education** | | | | | 1.07 | (0.33,3.46) | 1.06 | (0.33,3.44) |
| **Community-level of poverty** | | | | | 1.56 | (0.90,2.70) | 1.56 | (0.90,2.70) |
| **Random effects** | | | | | | | | |
| Community-level stdv | 0.47[a] | (0.36,0.62) | 0.40[a] | (0.29,0.55) | 0.36[a] | (0.25,0.52) | 0.36[a] | (0.25,0.52) |

Significance c: P<0.1; b: P <0.05 ; a: P<0.01; R: Reference category

**Table 4.4. Continued**

| | Malawi | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model1 | | Model2 | | Model3 | | Model4 | |
| Covariates | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI |
| **Health hazard level** | | | 1.03 | (0.99,1.07) | 1.04 | (0.98,1.10) | | |
| **Age & Health Hazard Interaction** | | | | | | | | |
| Age0*Health hazard | | | | | | | 1.01 | (0.94,1.09) |
| Age1-5*Health hazard | | | | | | | 1.00 | (0.90,1.10) |
| Age6-11*Health hazard | | | | | | | 0.99 | (0.91,1.09) |
| Age 12-23*Health hazard | | | | | | | 1.16[b] | (1.03,1.31) |
| Age 24-59*Health hazard | | | | | | | 1.22[a] | (1.06,1.40) |
| **Age(months)** | | | | | | | | |
| 0 | 1.72[a] | (1.46,2.03) | 1.72[a] | (1.46,2.03) | 1.72[a] | (1.46,2.02) | 1.81[a] | (1.52,2.16) |
| 1-5 | 0.79[b] | (0.65,0.95) | 0.79[b] | (0.65,0.95) | 0.79[b] | (0.65,0.95) | 0.83[b] | (0.68,1.01) |
| 6-11 | 1.00 | (0.83,1.20) | 1.00 | (0.83,1.20) | 1.00 | (0.83,1.20) | 1.06 | (0.88,1.28) |
| 12-23 | 0.88 | (0.72,1.07) | 0.88 | (0.72,1.07) | 0.88 | (0.73,1.07) | 0.90 | (0.73,1.10) |
| 24-59 (R) | | | | | | | | |
| **Sex** | | | | | | | | |
| Male | | | | | 1.18[a] | (1.07,1.31) | 1.18[a] | (1.07,1.31) |
| Female (R) | | | | | | | | |
| **Birth order and interval** | | | | | | | | |
| 1st (R) | | | | | | | | |
| 2nd & >=2 years | | | | | 0.62[a] | (0.51,0.76) | 0.62[a] | (0.51,0.76) |
| 2nd & < 2 years | | | | | 1.34[b] | (1.05,1.73) | 1.34[b] | (1.05,1.73) |
| 3+ & >= 2 years | | | | | 0.70[a] | (0.58,0.84) | 0.70[a] | (0.58,0.84) |
| 3+& <2 years | | | | | 1.35[a] | (1.09,1.68) | 1.36[a] | (1.09,1.68) |
| **Mother's age at birth** | | | | | | | | |
| Less than 20 years | | | | | 1.09 | (0.91,1.29) | 1.09 | (0.91,1.29) |
| 20-34 (R) | | | | | | | | |
| 35 or more years | | | | | 1.31[a] | (1.13,1.53) | 1.31[a] | (1.13,1.53) |
| **Mother's education** | | | | | | | | |
| No education | | | | | 1.28[b] | (1.02,1.60) | 1.28[b] | (1.03,1.60) |
| Primary | | | | | 1.31[a] | (1.09,1.57) | 1.31[a] | (1.09,1.57) |
| Secondary and above (R) | | | | | | | | |
| **Mother's HIV status** | | | | | | | | |
| Negative (R) | | | | | | | | |
| Positive | | | | | 2.83[a] | (2.24,3.56) | 2.83[a] | (2.24,3.56) |
| No test | | | | | 1.34[a] | (1.19,1.51) | 1.34[a] | (1.19,1.51) |
| **Household wealth** | | | | | | | | |
| Poor | | | | | 0.84[b] | (0.72,0.99) | 0.84[b] | (0.71,0.98) |
| Middle | | | | | 0.95 | (0.81,1.11) | 0.94 | (0.8,1.11) |
| Rich (R) | | | | | | | | |
| **Residence** | | | | | | | | |
| Urban (R) | | | | | | | | |
| Rural | | | | | 0.84 | (0.67,1.07) | 0.85 | (0.67,1.07) |
| **Community-level of health service** | | | | | 0.96 | (0.92,1.01) | 0.96 | (0.92,1.01) |
| **Community-level of mothers' education** | | | | | 0.89 | (0.51,1.55) | 0.88 | (0.50,1.53) |
| **Community-level of poverty** | | | | | 1.08 | (0.74,1.58) | 1.07 | (0.73,1.57) |
| **Random effects** | | | | | | | | |
| Community-level stdv | 0.38[a] | (0.30,0.47) | 0.38[a] | (0.30,0.47) | 0.36[a] | (0.28,0.45) | 0.36[a] | (0.28,0.45) |

Significance c: P<0.1; b: P <0.05 ; a: P<0.01; R: Reference category

**Table 4.4. Continued**

| | Niger | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model1 | | Model2 | | Model3 | | Model4 | |
| Covariates | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI |
| **Health hazard level** | | | 1.17[a] | (1.11,1.24) | 1.14[a] | (1.05,1.24) | | |
| **Age & Health Hazard Interaction** | | | | | | | | |
| Age0*Health hazard | | | | | | | 1.10[c] | (0.99,1.23) |
| Age1-5*Health hazard | | | | | | | 1.09 | (0.95,1.26) |
| Age6-11*Health hazard | | | | | | | 1.13[c] | (0.98,1.30) |
| Age 12-23*Health hazard | | | | | | | 1.22[a] | (1.06,1.40) |
| Age 24-59*Health hazard | | | | | | | 1.19[b] | (1.04,1.35) |
| **Age(months)** | | | | | | | | |
| 0 | 0.82b | (0.68,0.99) | 0.83[b] | (0.69,0.99) | 0.83[c] | (0.69,1.00) | 0.87 | (0.71,1.06) |
| 1-5 | 0.37[a] | (0.30,0.47) | 0.37[a] | (0.30,0.47) | 0.38[a] | (0.30,0.47) | 0.40[a] | (0.31,0.51) |
| 6-11 | 0.48[a] | (0.39,0.60) | 0.49[a] | (0.39,0.60) | 0.49[a] | (0.39,0.61) | 0.50[a] | (0.40,0.64) |
| 12-23 | 0.72[a] | (0.58,0.88) | 0.72[a] | (0.59,0.88) | 0.72[a] | (0.59,0.88) | 0.70[a] | (0.56,0.89) |
| 24-59 (R) | | | | | | | | |
| **Sex** | | | | | | | | |
| Male | | | | | 1.12[c] | (0.98,1.28) | 1.12[c] | (0.98,1.28) |
| Female (R) | | | | | | | | |
| **Birth order and interval** | | | | | | | | |
| 1st (R) | | | | | | | | |
| 2nd & >=2 years | | | | | 0.66[a] | (0.49,0.89) | 0.66[a] | (0.49,0.89) |
| 2nd & < 2 years | | | | | 1.08 | (0.75,1.55) | 1.08 | (0.75,1.55) |
| 3+ & >= 2 years | | | | | 0.79[c] | (0.62,1.03) | 0.80[c] | (0.62,1.03) |
| 3+& <2 years | | | | | 1.19 | (0.90,1.55) | 1.19 | (0.90,1.55) |
| **Mother's age at birth** | | | | | | | | |
| Less than 20 years | | | | | 1.07 | (0.85,1.36) | 1.08 | (0.85,1.36) |
| 20-34 (R) | | | | | | | | |
| 35 or more years | | | | | 1.12 | (0.93,1.36) | 1.12 | (0.93,1.36) |
| **Mother's education** | | | | | | | | |
| No education | | | | | 0.98 | (0.68,1.41) | 0.98 | (0.68,1.41) |
| Primary | | | | | 0.89 | (0.60,1.33) | 0.89 | (0.60,1.33) |
| Secondary and above (R) | | | | | | | | |
| **Mother's HIV status** | | | | | | | | |
| Negative (R) | | | | | | | | |
| Positive | | | | | 2.07 | (0.63,6.82) | 2.08 | (0.63,6.86) |
| No test | | | | | 1.07 | (0.94,1.22) | 1.07 | (0.94,1.22) |
| **Household wealth** | | | | | | | | |
| Poor | | | | | 0.88 | (0.72,1.07) | 0.88 | (0.72,1.07) |
| Middle | | | | | 0.86 | (0.69,1.05) | 0.85 | (0.69,1.05) |
| Rich (R) | | | | | | | | |
| **Residence** | | | | | | | | |
| Urban (R) | | | | | | | | |
| Rural | | | | | 1.76[a] | (1.16,2.66) | 1.76[a] | (1.16,2.66) |
| **Community-level of health service** | | | | | 1.09[a] | (1.03,1.16) | 1.09[a] | (1.03,1.16) |
| **Community-level of mothers' education** | | | | | 1.4 | (0.45,4.40) | 1.39 | (0.44,4.38) |
| **Community-level of poverty** | | | | | 1.13 | (0.71,1.82) | 1.13 | (0.71,1.81) |
| **Random effects** | | | | | | | | |
| Community-level stdv | 0.58[a] | (0.49,0.69) | 0.52[a] | (0.43,0.63) | 0.51[a] | (0.42,0.62) | 0.51[a] | (0.42,0.62) |

Significance c: P<0.1; b: P <0.05 ; a: P<0.01; R: Reference category

**Table 4.4. Continued**

| Covariates | Rwanda | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model1 | | Model2 | | Model3 | | Model4 | |
| | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI |
| **Health hazard level** | | | 1.15[a] | (1.07,1.24) | 1.15[a] | (1.04,1.26) | | |
| **Age & Health Hazard Interaction** | | | | | | | | |
| Age0*Health hazard | | | | | | | 1.14[b] | (1.01,1.29) |
| Age1-5*Health hazard | | | | | | | 1.07 | (0.90,1.28) |
| Age6-11*Health hazard | | | | | | | 1.11 | (0.92,1.34) |
| Age 12-23*Health hazard | | | | | | | 1.33[b] | 1.07,1.67) |
| Age 24-59*Health hazard | | | | | | | 1.2 | (0.90,1.60) |
| **Age(months)** | | | | | | | | |
| 0 | 4.13[a] | (2.89,5.90) | 4.13[a] | (2.89,5.9) | 4.13[a] | (2.89,5.9) | 4.20[a] | (2.89,6.12) |
| 1-5 | 1.62[b] | (1.09,2.39) | 1.62[b] | (1.09,2.39) | 1.62[b] | (1.10,2.40) | 1.68[b] | (1.12,2.53) |
| 6-11 | 1.62[b] | (1.09,2.41) | 1.62[b] | (1.09,2.41) | 1.63[b] | (1.10,2.42) | 1.67[b] | (1.10,2.53) |
| 12-23 | 1.33 | (0.88,2.02) | 1.33 | (0.88,2.02) | 1.33 | (0.88,2.03) | 1.27 | (0.81,1.98) |
| 24-59 (R) | | | | | | | | |
| **Sex** | | | | | | | | |
| Male | | | | | 1.16[c] | (0.97,1.38) | 1.16[c] | (0.97,1.38) |
| Female (R) | | | | | | | | |
| **Birth order and interval** | | | | | | | | |
| 1st (R) | | | | | | | | |
| 2nd & >=2 years | | | | | 0.89 | (0.66,1.22) | 0.89 | (0.66,1.22) |
| 2nd & < 2 years | | | | | 1.07 | (0.72,1.59) | 1.07 | (0.72,1.59) |
| 3+ & >= 2 years | | | | | 0.63[a] | (0.49,0.82) | 0.64[a] | (0.49,0.82) |
| 3+& <2 years | | | | | 1.57[a] | (1.17,2.11) | 1.58[a] | (1.17,2.12) |
| **Mother's age at birth** | | | | | | | | |
| Less than 20 years | | | | | 1.15 | (0.80,1.66) | 1.15 | (0.80,1.66) |
| 20-34 (R) | | | | | | | | |
| 35 or more years | | | | | 1.44[a] | (1.13,1.84) | 1.44[a] | (1.13,1.84) |
| **Mother's education** | | | | | | | | |
| No education | | | | | 1.19 | (0.79,1.79) | 1.19 | (0.79,1.79) |
| Primary | | | | | 0.96 | (0.67,1.39) | 0.97 | (0.67,1.39) |
| Secondary and above (R) | | | | | | | | |
| **Mother's HIV status** | | | | | | | | |
| Negative (R) | | | | | | | | |
| Positive | | | | | 2.67[a] | (1.71,4.18) | 2.67[a] | (1.71,4.18) |
| No test | | | | | 0.81b | (0.68,0.98) | 0.81b | (0.68,0.98) |
| **Household wealth** | | | | | | | | |
| Poor | | | | | 0.85 | (0.65,1.11) | 0.85 | (0.65,1.11) |
| Middle | | | | | 0.91 | (0.69,1.2) | 0.91 | (0.69,1.20) |
| Rich (R) | | | | | | | | |
| **Residence** | | | | | | | | |
| Urban (R) | | | | | | | | |
| Rural | | | | | 0.81 | (0.58,1.13) | 0.81 | (0.58,1.13) |
| **Community-level of health service** | | | | | 0.99 | (0.92,1.06) | 0.99 | (0.92,1.06) |
| **Community-level of mothers' education** | | | | | 0.68 | (0.25,1.87) | 0.68 | (0.25,1.86) |
| **Community-level of poverty** | | | | | 1.69[c] | (0.99,2.88) | 1.69[c] | (0.99,2.89) |
| **Random effects** | | | | | | | | |
| Community-level stdv | 0.39[a] | (0.24,0.62) | 0.35[b] | (0.20,0.61) | 0.31 | (0.16,0.61) | 0.31 | (0.16,0.61) |

Significance c: P<0.1; b: P <0.05 ; a: P<0.01; R: Reference category

**Table 4.4. Continued**

| | Senegal | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model1 | | Model2 | | Model3 | | Model4 | |
| Covariates | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI |
| **Health hazard level** | | | 1.12[a] | (1.06,1.17) | 1.05 | 0.97,1.14 | | |
| **Age & Health Hazard Interaction** | | | | | | | | |
| Age0*Health hazard | | | | | | | 1.00 | (0.91,1.09) |
| Age1-5*Health hazard | | | | | | | 1.07 | (0.95,1.21) |
| Age6-11*Health hazard | | | | | | | 0.99 | (0.86,1.15) |
| Age 12-23*Health hazard | | | | | | | 1.13 | (0.97,1.32) |
| Age 24-59*Health hazard | | | | | | | 1.33[a] | (1.13,1.58) |
| **Age(months)** | | | | | | | | |
| 0 | 3.11[a] | (2.38,4.06) | 3.11[a] | (2.38,4.06) | 3.16[a] | (2.42,4.14) | 3.89[a] | (2.82,5.36) |
| 1-5 | 1.16 | (0.86,1.57) | 1.16 | (0.86,1.57) | 1.18 | (0.88,1.60) | 1.41[c] | (1.00,2.01) |
| 6-11 | 0.71[b] | (0.50,0.99) | 0.71[b] | (0.50,0.99) | 0.72[c] | (0.51,1.01) | 0.88 | (0.60,1.29) |
| 12-23 | 0.79 | (0.56,1.11) | 0.79 | (0.56,1.11) | 0.80 | (0.57,1.12) | 0.92 | (0.62,1.37) |
| 24-59 (R) | | | | | | | | |
| **Sex** | | | | | | | | |
| Male | | | | | 1.26[a] | (1.08,1.47) | 1.26[a] | (1.08,1.47) |
| Female (R) | | | | | | | | |
| **Birth order and interval** | | | | | | | | |
| 1st (R) | | | | | | | | |
| 2nd & >=2 years | | | | | 0.71[b] | (0.54,0.95) | 0.71[b] | (0.54,0.95) |
| 2nd & < 2 years | | | | | 1.04 | (0.68,1.58) | 1.03 | (0.68,1.57) |
| 3+ & >= 2 years | | | | | 0.68[a] | (0.53,0.86) | 0.68[a] | (0.53,0.86) |
| 3+& <2 years | | | | | 1.41[b] | (1.07,1.85) | 1.41[b] | (1.07,1.85) |
| **Mother's age at birth** | | | | | | | | |
| Less than 20 years | | | | | 1.07 | (0.84,1.36) | 1.07 | (0.84,1.36) |
| 20-34 (R) | | | | | | | | |
| 35 or more years | | | | | 1.31[b] | (1.05,1.62) | 1.31[b] | (1.05,1.62) |
| **Mother's education** | | | | | | | | |
| No education | | | | | 2.24[a] | (1.41,3.54) | 2.24[a] | (1.42,3.55) |
| Primary | | | | | 1.60[c] | (0.99,2.57) | 1.61[c] | (1.00,2.58) |
| Secondary and above (R) | | | | | | | | |
| **Mother's HIV status** | | | | | | | | |
| Negative (R) | | | | | | | | |
| Positive | | | | | 2.56[b] | (1.09,5.98) | 2.53[b] | (1.08,5.92) |
| No test | | | | | 1.06 | (0.90,1.24) | 1.06 | (0.90,1.24) |
| **Household wealth** | | | | | | | | |
| Poor | | | | | 1.06 | (0.71,1.59) | 1.08 | (0.72,1.62) |
| Middle | | | | | 0.99 | (0.74,1.32) | 1.01 | (0.76,1.35) |
| Rich (R) | | | | | | | | |
| **Residence** | | | | | | | | |
| Urban (R) | | | | | | | | |
| Rural | | | | | 1.20 | (0.90,1.61) | 1.21 | (0.90,1.62) |
| **Community-level of health service** | | | | | 0.89[a] | (0.83,0.95) | 0.89[a] | (0.83,0.95) |
| **Community-level of mothers' education** | | | | | 1.79 | (0.80,4.01) | 1.79 | (0.80,4.02) |
| **Community-level of poverty** | | | | | 0.75 | (0.48,1.18) | 0.75 | (0.48,1.19) |
| **Random effects** | | | | | | | | |
| Community-level stdv | 0.43[a] | (0.32,0.57) | 0.40[a] | (0.28,0.54) | 0.34[a] | (0.22,0.51) | 0.34[a] | (0.22,0.51) |

Significance c: P<0.1; b: P <0.05 ; a: P<0.01; R: Reference category

**Table 4.4. Continued**

| Covariates | Zimbabwe | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model1 | | Model2 | | Model3 | | Model4 | |
| | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI | OR | 95%-CI |
| **Health hazard level** | | | 1.01 | (0.96,1.07) | 1.00 | (0.88,1.15) | | |
| **Age & Health Hazard Interaction** | | | | | | | | |
| Age0*Health hazard | | | | | | | 0.98 | (0.84,1.14) |
| Age1-5*Health hazard | | | | | | | 1.00 | (0.84,1.19) |
| Age6-11*Health hazard | | | | | | | 1.04 | (0.86,1.26 |
| Age 12-23*Health hazard | | | | | | | 1.01 | (0.83,1.23) |
| Age 24-59*Health hazard | | | | | | | 1.04 | (0.84,1.28) |
| **Age(months)** | | | | | | | | |
| 0 | 1.98[a] | (1.38,2.84) | 1.98[a] | (1.38,2.84) | 1.99[a] | (1.39,2.86) | 2.03[a] | (1.4,2.95) |
| 1-5 | 1.06 | (0.71,1.57) | 1.06 | (0.71,1.57) | 1.07 | (0.72,1.58) | 1.08 | (0.72,1.62) |
| 6-11 | 0.76 | (0.50,1.17) | 0.76 | (0.50,1.17) | 0.77 | (0.50,1.18) | 0.77 | (0.49,1.2) |
| 12-23 | 0.89 | (0.58,1.37) | 0.89 | (0.58,1.37) | 0.89 | (0.58,1.37) | 0.90 | (0.58,1.4) |
| 24-59 (R) | | | | | | | | |
| **Sex** | | | | | | | | |
| Male | | | | | 1.28[b] | (1.04,1.59) | 1.28[b] | (1.04,1.59) |
| Female (R) | | | | | | | | |
| **Birth order and interval** | | | | | | | | |
| 1st (R) | | | | | | | | |
| 2nd & >=2 years | | | | | 0.95 | (0.67,1.34) | 0.95 | (0.67,1.34) |
| 2nd & < 2 years | | | | | 1.31 | (0.67,2.54) | 1.31 | (0.67,2.54) |
| 3+ & >= 2 years | | | | | 1.21 | (0.86,1.69) | 1.21 | (0.86,1.69) |
| 3+& <2 years | | | | | 2.21[a] | (1.36,3.58) | 2.21[a] | (1.36,3.58) |
| **Mother's age at birth** | | | | | | | | |
| Less than 20 years | | | | | 1.23 | (0.88,1.73) | 1.23 | (0.88,1.73) |
| 20-34 (R) | | | | | | | | |
| 35 or more years | | | | | 1.09 | (0.76,1.56) | 1.09 | (0.76,1.56) |
| **Mother's education** | | | | | | | | |
| No education | | | | | 0.91 | (0.39,2.13) | 0.91 | (0.39,2.13) |
| Primary | | | | | 1.09 | (0.84,1.40) | 1.09 | (0.84,1.40) |
| Secondary and above (R) | | | | | | | | |
| **Mother's HIV status** | | | | | | | | |
| Negative (R) | | | | | | | | |
| Positive | | | | | 2.76[a] | (2.14,3.55) | 2.76[a] | (2.15,3.55) |
| No test | | | | | 1.98[a] | (1.49,2.65) | 1.98[a] | (1.48,2.65) |
| **Household wealth** | | | | | | | | |
| Poor | | | | | 1.20 | (0.71,2.05) | 1.20 | (0.71,2.05) |
| Middle | | | | | 1.23 | (0.83,1.82) | 1.24 | (0.84,1.83) |
| Rich (R) | | | | | | | | |
| **Residence** | | | | | | | | |
| Urban (R) | | | | | | | | |
| Rural | | | | | 0.91 | (0.59,1.40) | 0.91 | (0.59,1.40) |
| **Community-level of health service** | | | | | 0.87[a] | (0.8,0.94) | 0.87[a] | (0.8,0.94) |
| **Community-level of mothers' education** | | | | | 0.94 | (0.42,2.12) | 0.94 | (0.42,2.12) |
| **Community-level of poverty** | | | | | 0.68 | (0.33,1.39) | 0.68 | (0.33,1.39) |
| **Random effects** | | | | | | | | |
| Community-level stdv | 0.41[b] | (0.24,0.68) | 0.41[b] | (0.25,0.68) | 0.28 | (0.10,0.8) | 0.28 | (0.10,0.79) |

Significance c: P<0.1; b: P <0.05 ; a: P<0.01; R: Reference category

### 4.3.2. Effect of household environmental health hazards on under-five mortality

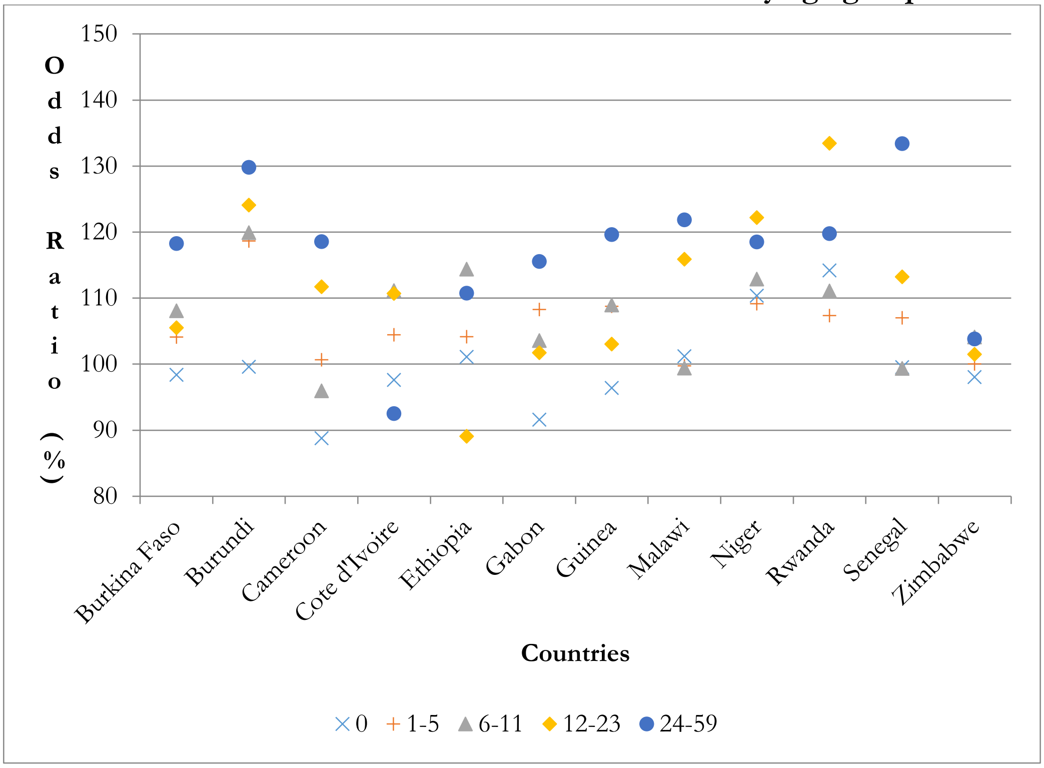
Table 4.4 presents the results for the fitted models 1 to 4. It is worthwhile to remind that the index of household environmental health hazards is in a continuous scale and increasing values of the index imply an increase in the level of environmental health hazards. This sub-section presents the result under model2 and model3. Model2 has only household environmental index and age (which is basically used to capture the shape of the hazard function). This model enables to assess the effect of household environmental health hazards on under-five mortality without controlling for the effects of other covariates. The odds ratio associated with this covariate is significantly greater than one in all countries, except in Gabon, Malawi and Zimbabwe. This suggests that the risk of mortality is positively associated with the level of household environmental health hazards.

However, after controlling for the effects of other covariates that are included in the study, the result under model3 shows that the effect of the level of household environmental health hazards on under-five mortality remains significant in three countries: Burundi ($P<0.05$), Niger ($P<0.01$) and Rwanda ($P<0.01$). After controlling for the effects of other covariates, a unit increase in the potential level of health hazards in the household environment increases the odds of risk of under-five mortality by 11, 14 and 15 per cent in Burundi, Niger and Rwanda, respectively. It is worth to note that model3 assumes that the effect of health hazards on under-five mortality is the same regardless of duration (or the ages of children). However, based on descriptive graphs on the age pattern of risk of death by the level of health hazards in the previous section, it is noted that the effect of household environmental health hazards is noticeable among older children than younger ones. The following sub-sections presents the result in relation to how the effect of the level of health hazards is modified by the age of the child by considering a model that takes into account the interaction between age and the index of household environmental health hazards.

### 4.3.3. Interaction between household environmental health hazards and age

Model4 in Table 4.4 provides separate effects for the index of household environmental health hazards for each age group. After controlling for the effects of other covariates, the result under model4 indicates that the effect of household environmental health hazards on the risk of death is significant depending on the ages of children in eight countries out of 12: Burkina Faso, Burundi, Cameroon, Guinea, Malawi, Niger, Rwanda and Senegal.

**Figure 4.2. Effect of household environmental health hazards by age groups**




For clarity, the odds ratios in Table 4.4 corresponding to the interaction effects are depicted in Figure 4.2. The figure shows clearly that the effect of household environmental health hazards is noticeable for the age interval 24-59 months. Its effect is significant for seven countries for this age group: Burkina Faso, Burundi, Cameroon, Guinea, Malawi, Niger, and Senegal. A unit increase in the index of household environmental health hazards increases the odds of risk of death by 18 ($P<0.05$) per cent in Burkina Faso to 33 per cent ($P<0.01$) in Senegal. Furthermore, its effect is quite prominent in Senegal and Burundi (Odds ratio, 1.30).

Comparatively, increase in the index of household environmental health hazards is significantly associated with increased risk of mortality for the 12-23 months interval in four countries: Cameroon, Malawi, Niger, and Rwanda. A unit increase in the index is associated with an increase in the odds of mortality by 12 ($P<0.1$) per cent in Cameroon to 33 ($P<0.05$) per cent in Rwanda.

On the other hand, the result suggests that the effect of household environmental health hazards is less important for other age groups (i.e. during infancy). Specifically, its effect for the age groups 0, 1-5, and 6-11 months intervals are significant in 2, 1 and 3 countries, respectively. To sum up, the result under model4 substantiates the evidence, which is noted in the previous section based on descriptive graphs that indicate a relatively stronger and more substantial effect of household environmental health hazards on risk of death during late childhood.

### 4.3.4. Effects of other covariates

This sub-section also makes use of the result under model4. Subsequent paragraphs present the effects of bio-demographic factors, socioeconomic and community-level covariates.

#### 4.3.4.1. Effects of bio-demographic factors

After adjusting for the effects of other covariates, the sex of the child has a significant association with under-five mortality in all countries, except in Burundi. Moreover, the result consistently reveals that the risk of under-five deaths is higher for male children than female children. The risk of under-five deaths among male children relative to female children is lowest in Cameroon and Niger (odds ratio, 1.12) and highest in Cote d'Ivoire (odds ratio, 1.64).

After controlling for the effects of other covariates, the effect of birth-order and birth-interval on under-five mortality is significant for all countries. The reference category for this covariate is first-birth. The odds of risk of death among children whose birth-order are three or more and their corresponding birth-interval are shorter than 24 months is significantly greater than the odds of risk of death for first-born children, except in Burundi and Niger. Besides, the odds ratios range from 1.36 in Malawi to 2.21 in Zimbabwe. This implies that the odds of risk of death for children whose birth-orders are three or greater and their corresponding birth-intervals are shorter than 24 months is 1.36 times the corresponding odds for first-born children in Malawi. The corresponding multiplication factor is 2.21 times in Zimbabwe. The odds ratios corresponding to children with second birth-order and long birth-intervals are significant for eight countries. Besides, these significant odds ratios vary from 0.62 in Malawi to 0.77 in Burkina Faso and Ethiopia. This suggests that the risk of death for first-born children is higher than for second-born children with long birth-intervals. The odds ratios corresponding to second-born children with short birth-intervals are significant for five countries with values ranging from 1.34 in Malawi to 2.32 in Gabon. This suggests that long birth-interval enhances child survival. Further supporting evidence can be seen from the odds ratios corresponding to children with third or more birth-orders but with long birth-interval which are significant for six countries. These odds ratios vary from 0.56 in Burundi to 0.80 in Niger. This strengths the evidence that long birth-interval enhances child survival even among high-order births. In general, the result suggests that combinations of short birth-interval and high-order births are associated with a high risk of under-five mortality.

After adjusting for the effects of other covariates, the age of the mother at child's birth is significantly associated with under-five mortality in seven countries. In particular, the risk of under-five mortality among children born to mothers older than 34 years and younger than 20 years tends to be greater than for those children born to mothers of 20-34 years old (the reference category). In particular, the odds ratios corresponding to children from youngest mothers are only highly significant in Burkina Faso and Ethiopia with corresponding values 1.33 and 1.60, respectively. The odds ratio corresponding to children from oldest mothers are significant for six countries, namely, Cote d'Ivoire, Ethiopia, Gabon, Malawi, Rwanda and Senegal. Their values vary from 1.23 in Cote d'Ivoire to 1.56 in Gabon. This clearly indicates the higher risk of under-five mortality for children born to old mothers relative to the reference group. It is clear from the above information that the relative odds for both categories (i.e. <20 and >34 years) are significant only for Ethiopia. The above result suggests a non-linear effect of mothers' age.

HIV status of the mother is significantly associated with under-five mortality in all countries, except in Burundi, Gabon and Niger. The odds of under-five mortality among children of HIV-positive mothers relative to HIV-negative mothers varies from 1.86 ($P<0.05$) times in Cote d'Ivoire to 2.83 ($P<0.01$) times in Malawi. This implies that children of HIV-positive mothers have higher risk of under-five deaths than children of HIV-negative mothers.

#### 4.3.4.2. Effects of socioeconomic factors

The result in Table 4.4 for model4 indicates that mothers' education is significantly associated with under-five mortality in six countries, namely, Burundi, Cameroon, Gabon, Guinea, Malawi, and Senegal after controlling for the effects of other covariates. In all of these countries, children whose mothers have secondary and above education have lower under-five mortality than children whose mothers have primary or no education. In particular, the risk of under-five mortality among children of mothers with no education relative to children of mothers with secondary and above education is lowest in Malawi (odds ratio, 1.28) and highest in Burundi (odds ratio, 2.44). Comparatively, the risk of death among children of mothers with primary education relative to children of mothers with secondary and above education is lowest in Cameroon (odds ratio, 1.26) and highest in Burundi (odds ratio, 1.99). These relative odds tend to be less than the relative odds corresponding to children whose mothers have no education. This suggests that even children of mothers with primary education tend to have less risk of death than children whose mothers do not have education.

Unlike the moderately strong evidence for the association between mothers' education and under-five mortality, the effect of household wealth is found to be significant only in two countries: Guinea and Malawi. In particular, the odds of risk of death among children who live in households with medium wealth status is 1.42 ($P<0.05$) times that of children from rich households in Guinea. On the contrary, the odds of risk of death for children from poor households is 16 ($P<0.05$) per cent less than that of children from rich households in Malawi. Clearly the evidence is weak for the relationship between household wealth and under-five mortality after controlling for the effects of other covariates. I have tried to assess the possible causes, especially the effect of some co linearity between the index of household environmental health hazards and wealth. To do this, I fit two separate full models with the exception of wealth index or household environmental health hazards. The fitted models suggest similar results with the model that includes all covariates (model3).

#### 4.3.4.3. Effects of community characteristics and unobserved heterogeneity

Model4 is referred to assess the effects of community level characteristics on under-five mortality. To begin with the type of residence of the community has a significant effect on under-five mortality only in Niger. In this country, the risk of death among under-five children who live in rural communities is greater than the corresponding risk among children who live in urban communities after controlling for the effects of other covariates.

By contrast, after adjusting for the effects of other covariates, the effect of health service accessibility is moderately ($P<0.05$) to highly significant ($P<0.01$) in six of the twelve countries: Burkina Faso, Burundi, Cote d'Ivoire, Niger, Senegal and Zimbabwe. With the exception of Niger, increased accessibility of health service reduces the risk of under-five mortality in all the above countries. This reduction in the odds of risk of under-five deaths varies from 5 ($P<0.05$) per cent in Burkina Faso to 13 ($P<0.01$) per cent in Zimbabwe for every unity increase in the index of health service accessibility. On the contrary, the risk of under-five mortality increases with increase in the index of health service accessibility in Niger. This is probably due to reverse causation where access is made available through intervention in areas where mortality is higher.

Other than the above community characteristics, the community-level of women's education and community-level of poverty are found to be significant in only one and two countries, respectively. In particular, the proportion of women who have secondary education and above has a negative significant effect on under-five mortality only in Cameroon. In this country, the odds of risk of under-five deaths decreases by 43 ($P<0.05$) per cent for a unit increase in the percentage of women who have secondary and above education in the community. On the other hand, the percentage of poor households in the community has a positive significant relationship with under-five mortality in Burkina Faso and Rwanda. In both countries, a unit increase in the percentage of poor households in the community increases the odds of under-five deaths by 69 per cent. Finally, the result under model4 indicates that none of the community-level characteristics are significantly associated with under-five mortality in Ethiopia, Gabon, Guinea and Malawi after controlling for the effects of individual and household-level variables.

Looking at Table 4.3, generally, it is clear that the ICC is least for model4. This implies that the clustering effects of being in the same community on under-five mortality is reduced or accounted for by the covariates included in the study. However, the intra-class correlations in the same table (or equivalently the standard deviation of the random effect in Table 4.4) under model4 are significant for all countries, except for Gabon and Zimbabwe. This implies that there are significant unobserved sources of heterogeneities in under-five mortality unaccounted for by the existing covariates in those countries.

# 5. DISCUSSIONS AND CONCLUSIONS

This chapter presents the discussions and conclusions of the study. The discussions are organized into three sub-sections. The first sub-section focuses on the main contribution of the paper while the second sub-section comments on other findings of secondary importance and the third sub-section deals with the limitation of the study.

## 5.1. Discussions

### 5.1.1. The main contribution of the paper

This study estimates the effect of household environmental health hazards on under-five mortality in 12 countries in sub-Saharan Africa. In unadjusted model, I have found that an increase in the level of household environmental health hazards is associated with increased risk of under-five mortality in all countries, except in Gabon, Malawi and Zimbabwe. After adjusting for the effects of a number of factors, it remains significant in three countries: Burundi, Niger and Rwanda. This finding suggests that the effect of household environmental health hazards on under-five mortality is not definitive across countries. This is in agreement with past studies, which do not reach at a definite conclusion about the effects of environmental factors on child health and survival. While a number of studies affirm the significant effects of environmental factors, including sources of water , sanitation and the type of flooring material on child health and survival (Martin, Trussell, Salvail and Shah 1983; Trussell and Hammerslough 1983; Esrey, Feachem and Hughes 1985; Woldemicael 2000; Fayehun 2010; Mesike and Mojekwu 2012), other studies find their effects as non-significant. A study by Lemani (2013) in Malawi finds that the effect of environmental factors, including source of water, type of toilet facility and type of floor material have non-significant effect on infant and child mortality after adjusting for the effects of other covariates. The study by Manda (1998) has also found similar result about the effect of source of water on infant mortality after controlling for the effects of other covariates. The study by Omariba, Beaujot and Rajulton (2007) also finds a significant effect of type of toilet facility and a non-significant effect of water source.

In addition, cross-national studies have also shown that the effects of environmental factors are not consistently significant across countries. In particular, the study by Fayehun (2010) indicates that increased environmental health hazards is significantly associated with increased risk of under-five mortality for high mortality countries but not for low mortality countries. Based on a cross-national study, Timaeus and Lush (1995) also reach inconclusive result about the effect of environmental factors on mortality among children aged 6 to 36 months old. In particular, they conclude that environmental factors explain socioeconomic differential in mortality and diarrheal prevalence mainly in one of the four countries included in their studies.

Researchers offer a number of reasons for the inconclusive result about the effects of environmental factors on child health and mortality across studies. Some suggest that the inability to control a range of confounders as one of the reasons (Blum and Feachem 1983; Timaeus and Lush 1995). Linking survey data sets with administrative or municipality records on environmental conditions might also provide the opportunity to narrow the information gap about a number of potential environmental factors that might influence child health and mortality, which cannot be made available through survey methods (Sastry 1996). Moreover, it is obvious that availability of a safe source of drinking water and better sanitation facility do not necessarily guarantee avoiding potential health risks unless it is complemented by hygienic practice and better water storage that can reduce health risks, including diarrhoeal diseases and worm infections (Esrey, Potash, Roberts and Shiff 1991; Jinadu, Olusi, Agun and Fabiyi 1991 ). Besides, failure to assess interaction between the age of the child and environmental exposure might also undermine the potential influence of environmental factors on child health and survival (Blum and Feachem 1983). In this study, I have tried to assess the possibility of such interaction between household environmental health hazards and the age of the child.

While the relatively limited evidence about the effect of household environmental health hazards on the risk of under-five mortality which is found in three countries, its effect on risk of death is found to be significant in 8 of the 12 countries that are included in the study when its effect is assessed separately for different age groups by considering interaction with age. These countries are Burkina Faso, Burundi, Cameroon, Guinea, Malawi, Niger, Rwanda and Senegal. The findings suggest that the age of the child modifies the effect of environmental health hazards on risk of mortality. Of these eight countries, the effect of increasing in the level of household environmental health hazards is associated with increasing risk of death among children 24-59 (or child) and 12-23 (or toddlers) months of age in seven and four countries, respectively. However, its effect on the risk of mortality among younger children/infants is found to be significant in relatively smaller number of countries. Further, in countries where the effect of household environmental health hazards on the risk of death is significant other than among older children, the magnitude of its effect is substantial among older children than younger ones. Previous studies also affirm the age-dependence of the effects of environmental factors on child health and survival (Trussell and Hammerslough 1983; Rutstein 2000; Woldemicael 2000).

On the other hand, while studies in Malawi by Lemani (2013) and Manda (1998) find a non-significant effect of environmental factors on child survival after controlling for the effects of other covariates, this study has shown that increasing levels of household environmental health hazards is significantly associated ($P<0.01$) with increasing risk of mortality during childhood period (i.e. 24-59 months) after adjusting for the effects of socioeconomic, bio-demographic and community characteristics in the same country. Moreover, the study by Fayehun (2010) reveals a significant effect of environmental health hazards on risk of under-five mortality in high mortality countries but not in low mortality countries. By contrast, this study finds a significant effect of household environmental health hazards on risk of death in relatively low mortality countries, including Senegal. These differing findings are, perhaps, partly attributed to the inability by the above studies to assess the effects of environmental factors separately for sub-groups and differences in the measurement of household environmental conditions.

In general, the findings suggest that children are potentially exposed to household environmental health hazards when they grow older, probably begin to interact with the environment around them and begin to feed on other food staff other than breast milk. These household environmental health hazards can be of various sources, including water, soil, and air (Mosley and Chen 1984). Given younger children are fed mainly on breast milk, they are less likely exposed to health risks. In connection to this, a study in Nigeria and Ghana by Ahiadeke (2000) indicates higher risk of diarrhoeal diseases among mixed-fed infants than among exclusively breast-fed infants in areas with poor sanitation. This suggests that the household environmental conditions do not necessarily threat the health of children unless they come into direct contact (for instance, through feeding). Especially, the relatively weak effect of environmental health hazards on risk of death among neonates is perhaps due to exclusive breast feeding during this period, which helps to avoid exposure to food and water contamination. In general, the weaker effect of environmental health hazards during infancy than childhood is perhaps partly explained by the fact that bio-demographic factors are more important during infancy while socioeconomic, cultural and hygienic factors play a role in childhood period (Omariba, Beaujot and Rajulton 2007). However, the current study does not address such possible confounders, including breast feeding, nutrition, childcare, and hygiene that might clarify the mechanisms for differential effects of environmental health hazards according to the age of the child.

### 5.1.2. Other findings

After adjusting for the effects of a number of socioeconomic and community characteristics, the bio-demographic variables are, generally, significant in most of the countries included. Their effects agree, in general, with what have been found by previous studies.

The result reveals consistently that the risk of under-five mortality is higher among males than females. This finding is in agreement with the firmly established sex differential in mortality in the demographic literature (Trussell and Hammerslough 1983; Hill and Upchurch 1995; Sastry 1996; Boco 2010; Lemani 2013). This finding suggests that sex differential in mortality is mainly driven by preconception environmental factors and/or biological forces (Pongou 2013).

The effect of a combination of birth-order and birth-interval on under-five mortality is significant for all countries. In general, combinations of short birth-interval and high-order births are associated with a high risk of under-five mortality. Given the accumulated knowledge about the negative effect of short birth-interval and high birth-orders on child survival, the current consistent finding across countries in the study is not surprising (Trussell and Hammerslough 1983; Koenig, Phillips, Campbell and D'Souza 1990; Miller, Trussell, Pebley and Vaughan 1992; Bolstad and Manda 2001; Omariba, Beaujot and Rajulton 2007; Boco 2010).

The study finds the age of mother at childbirth as a significant covariate of under-five mortality in seven countries: Burkina Faso, Cote d'Ivoire, Ethiopia, Gabon, Malawi, Rwanda, and Senegal. In six of the above countries, the odds of death among under-five children born to the oldest mothers (>34 years) is significantly greater than those born to mothers between 20 and 34 years old. The findings are, in general, consistent with previous studies (Omariba, Beaujot and Rajulton 2007; Boco 2010).

HIV status of the mother is significantly associated with under-five mortality in all countries, except in Burundi, Gabon and Niger. The study finds higher under-five mortality among children of HIV-positive mothers. This is consistent with past studies (Mogford 2004; Gakidou, Cowling, Lozano and Murray 2010; Lemani 2013).

The positive effect of maternal education on child survival is even evident after controlling for the effects of a number of factors in six countries: Burundi, Cameroon, Gabon, Guinea, Malawi, and Senegal. This finding is in agreement with the rich empirical evidence on the positive effect of maternal education on child health and survival (Martin, Trussell, Salvail and Shah 1983; Buor 2003; Mogford 2004; Gakidou, Cowling, Lozano and Murray 2010; Pamuk, Fuchs and Lutz 2011; Song and Burgard 2011).

Unlike the substantial evidence for the association between mothers' education and under-five mortality, the effect of household wealth is found to be significant only in two countries: Guinea and Malawi. While risk of under-five mortality among children from households with medium wealth status is greater than those from rich households in Guinea, risk of under-five mortality among children from poor households is significantly less than those from rich households in Malawi. Using the same data in Malawi, Lemani (2013) finds similar contradictory evidence. This might be attributable to the measurement involved in wealth index. In addition, this study has examined for potential effects of some co linearity by fitting two separate full models with the exception of wealth index or household environmental health hazards. The fitted models suggest similar results with the model that includes all covariates.

Though community characteristics might help to explain part of the heterogeneity (ICC) in under-five mortality in most of the countries that are included in the study, they are found to be significant in relatively small number of countries. Previous studies also suggest weak evidence on the effect of community characteristics on child survival (Sastry 1996; Boco 2010). On the other hand, the effect of accessibility of health services in the community is significantly associated with under-five mortality in several countries: Burkina Faso, Burundi, Cote d'Ivoire, Niger, Senegal and Zimbabwe. An increase in the accessibility of health service index reduces the risk of under-five mortality, except in Niger. This result is in agreement with previous studies based on related variables, including the percentage of fully immunized children in the community and the percentage of children who are delivered in health facilities (Boco 2010; Adedini, Odimegwu, Imasiku*, et al.* 2014 ).

### 5.1.3. Limitation of the study

Having commented on the main findings of this study, it is to be stressed that the study is not free from limitations. First, this study enables to see the overall impact of environmental health hazards on child survival as opposed to the impact of individual environmental factors. This makes it possible to fit a parsimonious model and assess interaction with ease. However, the procedure costs loss of some information and does not provide the opportunity to identify the sources of environmental health hazards, which are relatively important. Second, indicators of availability of improved toilet and water source are not enough to clearly understand the potential effects of household environmental health hazards unless they are complemented by potential confounders like sanitary practice in child faeces removal, food preparation, water storage, waste management, and proper latrine utilization. Unfortunately, this study does not address these issues partly due to limitation of information. Third, the notion of environmental health hazards involves a number of other issues other than the indicators that are incorporated in this study. Hence, the results cannot be generalized to all sources of environmental health hazards. Fourth, environmental health constitutes broad issues, including climate, altitude, temperature and industrial waste in which their effects can be felt at the broader community-level (Sastry 1996; Root 1999; Balk, Pullum,S toreygard*, et al.* 2004). However, due to unavailability of environmental indicators at the cluster-level, this study does not address issues beyond the household environment. Fifth, the study assumes proportionality of effects of covariates. Hence, the reliability of the results depends on the validity of this assumption. Finally, since the data source is a cross-sectional survey, the effects of predictors that can change in the course of time like household wealth status and the household environmental conditions might be obscured. Thus, better research design, notably longitudinal studies, might lead to better results.

## 5.2. Conclusions

This study has attempted to understand the effect of the household environmental condition on under-five mortality in sub-Saharan Africa using DHS data sets from 12 countries in the region. The study has employed principal component method to construct an index of the household environmental health hazards level using a number of indicators: water source, type of toilet facility, flooring material, type of wall, type of roof, cooking fuel and the water source location as proxy for quantity of water. A number of socioeconomic, bio-demographic and community characteristics are also identified from the literature as control variables. Multilevel discrete-time hazard model is used to assess the relationship between the level of environmental health hazards and under-five mortality after controlling for the effects of a number of socioeconomic, bio-demographic and community characteristics. The study finds that under-five mortality varies across communities in most of the countries in the study. The significance of the clustering effect justifies the use of multilevel approach that makes the result comparatively robust than had it been employed traditional approaches.

After controlling for the effects of other factors, the study finds a significant positive association between under-five mortality and level of household environmental health hazards in three countries: Burundi, Niger and Rwanda. The large number of countries where the effect turns out to be non-significant may be because of the assumption of same effect (or proportional odds in the hazard) of covariates on the risk of death at different stages of the child's development (or age) which is the underlying assumption in discrete-time hazard models. An assessment of interaction effects indicates that the effect of household environmental health hazards on the risk of death depends on the age of the child in eight countries: Burkina Faso, Burundi, Cameroon, Guinea, Malawi, Niger, Rwanda and Senegal. In general, increasing level of household environmental health hazards is consistently associated with increasing risk of death during 24-59 months after birth. However, its effect is less noticeable among young children. Moreover, while the effect of household environmental health hazards in the West African Countries of Burkina Faso, Senegal, and Guinea is significant only for late childhood period (24-59 months), its effect is significant during early childhood periods other than late childhood period in Burundi, Cameroon, Malawi, and Niger.

In general, the findings of the study imply that exposure to environmental health risks is substantial during late childhood when children begin to interact with the environment around them. This has an implication on the management of household environmental health risks that may affect intermediate child health outcomes. In particular, household cleanliness, poor storage of water, and inadequate sanitation are related to diarrhoeal diseases (Jinadu, Olusi, Agun and Fabiyi 1991; Ahiadeke 2000; Bartlett 2005). It is to be reminded that diarrhoeal diseases are among the major causes of under-five deaths in Africa (UNECA, AU, AfDB and UNDP 2013). Moreover, intermediate health outcomes (including pneumonia, anaemia and respiratory diseases) are related to use of biomass cooking fuel (Boy, Bruce and Delgado 2002; Mishra and

Retherford 2006; Pongou, Ezzati and Salomon 2006; Dherani, Pope, Mascarenhas*, et al.* 2008; Fuentes-Leonarte, Ballester and Ten´ıas 2009; Kyu,Georgiades and Boyle 2010). These and other intermediate child health outcomes determine child survival. The coverage of safe drinking water and improved sanitation is low in sub-Saharan Africa (UNICEF and WHO 2012). Given the substantial negative effect of poor household environmental conditions on child survival that is found, the effort to enhance child health and survival through improving the environment is worth pursuing.

The study has found relationships between under-five mortality and bio-demographic factors, which are generally similar to findings from previous studies. In general, under-five mortality is relatively high among male children, children of young or old mothers, children of HIV-positive mother, and children associated with short birth-interval and high birth-orders. Substantial evidence is also found about the link between health service accessibility in the community and under-five mortality. Besides, the study has found, generally, a negative relationship between maternal education and under-five mortality. Researchers translate similar findings into recommendations of improving use of contraception and promoting women's education to influence birth interval, use of maternal and child care services.

The study suggests that further investigations on the subject that combine survey data with other sources will help to enhance knowledge on the broader aspect of environmental health hazards. Moreover, further studies should also seek to improve knowledge on the causes of high risk of death during 24-59 months due to exposure to environmental health hazards.

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# APPENDIX

## Appendix 1. Percentage distribution of missing observations by survival status

| Covariates | Burkina Faso | | Burundi | | Cameroon | |
|---|---|---|---|---|---|---|
| | Alive | Dead | Alive | Dead | Alive | Dead |
| **Sex** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Birth order and interval** | 0.1 | 0.5 | 0.2 | 1.0 | 0.3 | 1.0 |
| **Mother's age at birth** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Mother's education** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Mother's HIV status** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Household wealth** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Residence** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Household health hazard level** | 0.2 | 0.2 | 0.9 | 1.0 | 0.5 | 1.1 |
| **Community level of health service** | 0.0 | 0.0 | 0.4 | 1.0 | 0.0 | 0.0 |
| **Community level of mothers' education** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Community level of poverty** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Missing observations for at least one covariate (%)** | 0.3 | 0.6 | 1.4 | 2.7 | 0.8 | 2.1 |
| **Total target samples** | 13717 | 1328 | 7231 | 511 | 10734 | 998 |
| **Total target samples with no missing** | 13674 | 1320 | 7128 | 497 | 10653 | 977 |

## Appendix 1. Continued

| Covariates | Cote d'Ivoire | | Ethiopia | | Gabon | |
|---|---|---|---|---|---|---|
| | Alive | Dead | Alive | Dead | Alive | Dead |
| **Sex** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Birth order and interval** | 0.2 | 1.6 | 0.1 | 1.1 | 0.3 | 0.3 |
| **Mother's age at birth** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Mother's education** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Mother's HIV status** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Household wealth** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Residence** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Household health hazard level** | 0.5 | 0.4 | 0.3 | 0.4 | 0.9 | 0.3 |
| **Community level of health service** | 0.0 | 0.0 | 3.1 | 1.5 | 0.0 | 0.0 |
| **Community level of mothers' education** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Community level of poverty** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Missing observations for at least one covariate (%)** | 0.7 | 2.0 | 3.4 | 2.8 | 1.2 | 0.6 |
| **Total target samples** | 7093 | 683 | 10808 | 846 | 5747 | 320 |
| **Total target samples with no missing** | 7044 | 669 | 10437 | 822 | 5677 | 318 |

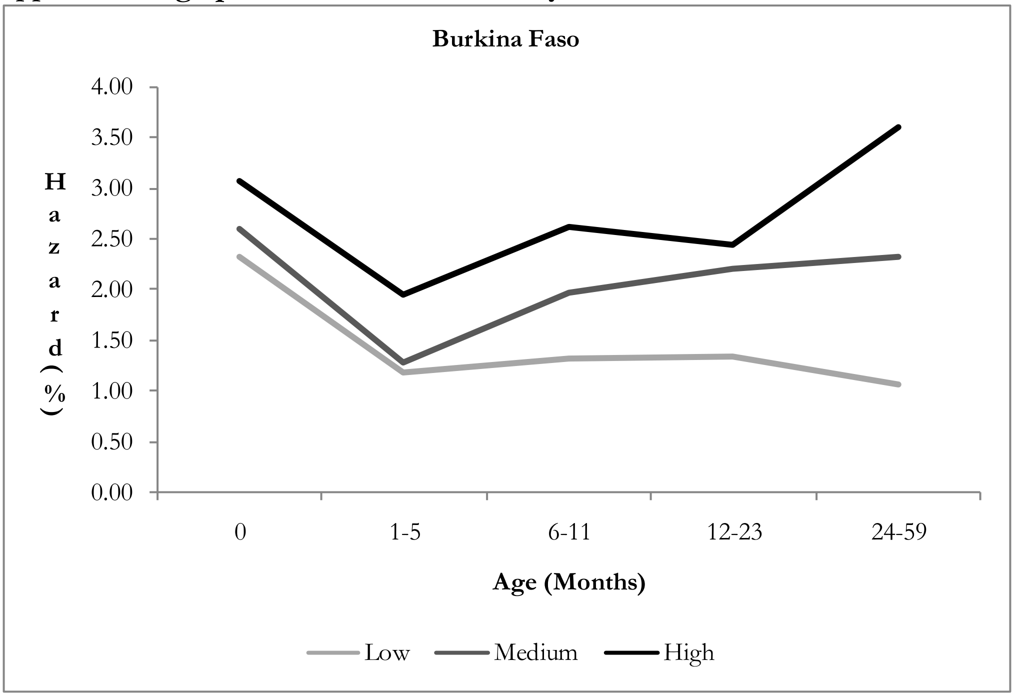
## Appendix 1. Continued

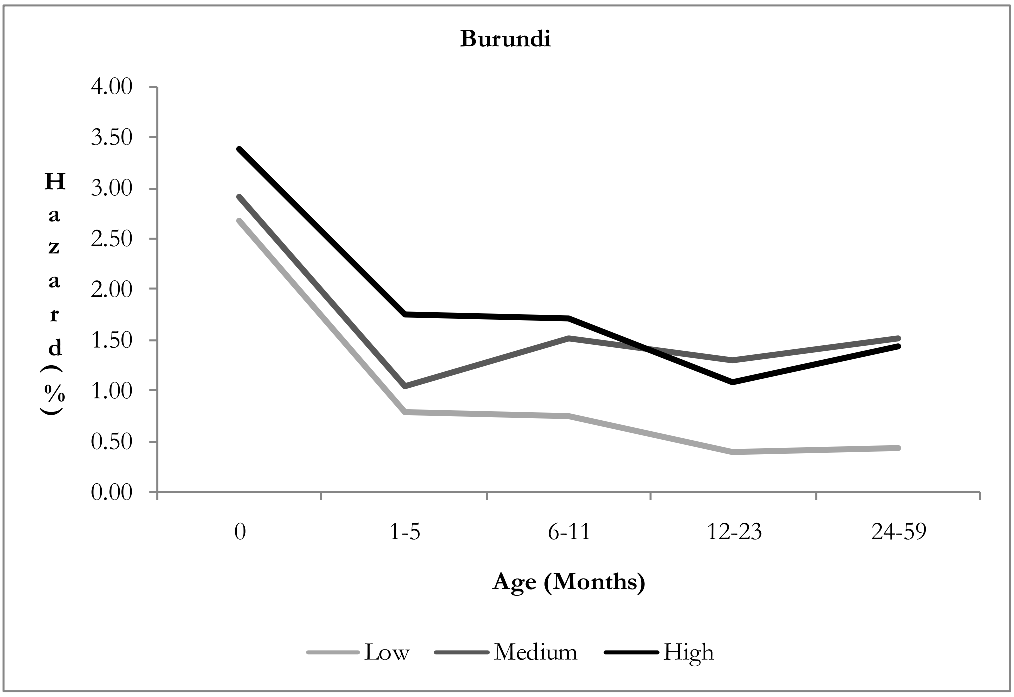
| Covariates | Guinea | | Malawi | | Niger | |
|---|---|---|---|---|---|---|
| | Alive | Dead | Alive | Dead | Alive | Dead |
| **Sex** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Birth order and interval** | 0.1 | 0.5 | 0.1 | 0.4 | 0.2 | 0.2 |
| **Mother's age at birth** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Mother's education** | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 |
| **Mother's HIV status** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Household wealth** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Residence** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Household health hazard level** | 0.2 | 0.0 | 0.2 | 0.0 | 0.2 | 0.2 |
| **Community level of health service** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Community level of mothers' education** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Community level of poverty** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Missing observations for at least one covariate (%)** | 0.4 | 0.5 | 0.4 | 0.4 | 0.5 | 0.5 |
| **Total target samples** | 6424 | 615 | 18360 | 1607 | 11602 | 956 |
| **Total target samples with no missing** | 6400 | 612 | 18293 | 1601 | 11540 | 951 |

## Appendix 1. Continued

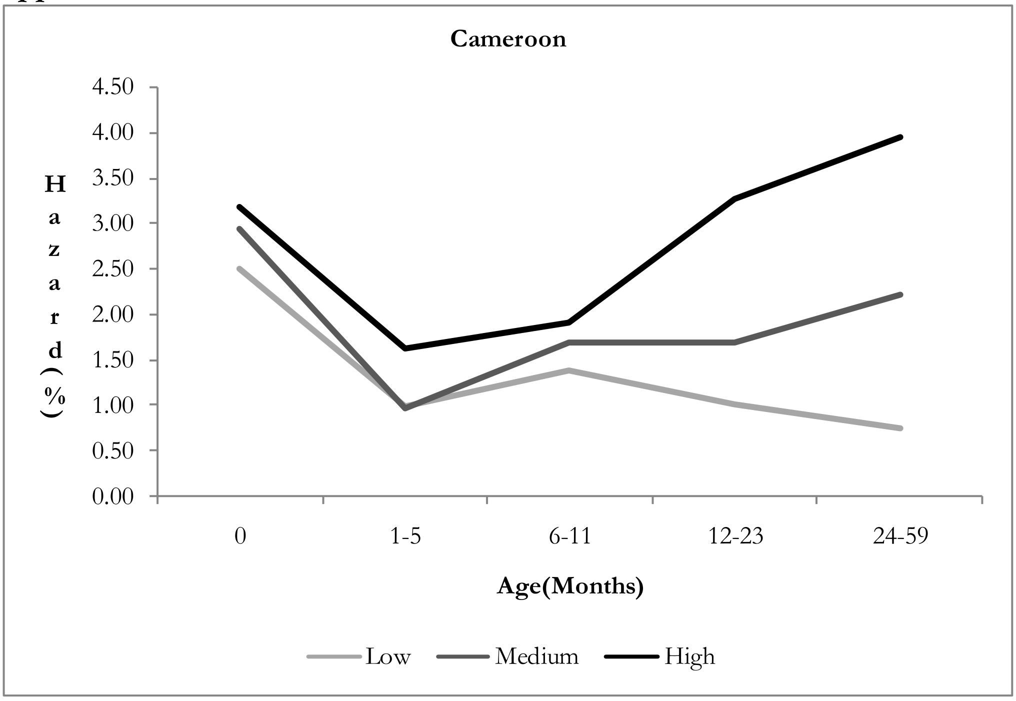
| Covariates | Rwanda | | Senegal | | Zimbabwe | |
|---|---|---|---|---|---|---|
| | Alive | Dead | Alive | Dead | Alive | Dead |
| **Sex** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Birth order and interval** | 0.3 | 1.4 | 0.2 | 2.0 | 0.2 | 1.4 |
| **Mother's age at birth** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Mother's education** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Mother's HIV status** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Household wealth** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Residence** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Household health hazard level** | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Community level of health service** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Community level of mothers' education** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Community level of poverty** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Missing observations for at least one covariate (%)** | 0.7 | 1.4 | 0.2 | 2.0 | 0.2 | 1.4 |
| **Total target samples** | 8484 | 518 | 11635 | 702 | 5203 | 360 |
| **Total target samples with no missing** | 8428 | 511 | 11613 | 688 | 5192 | 355 |

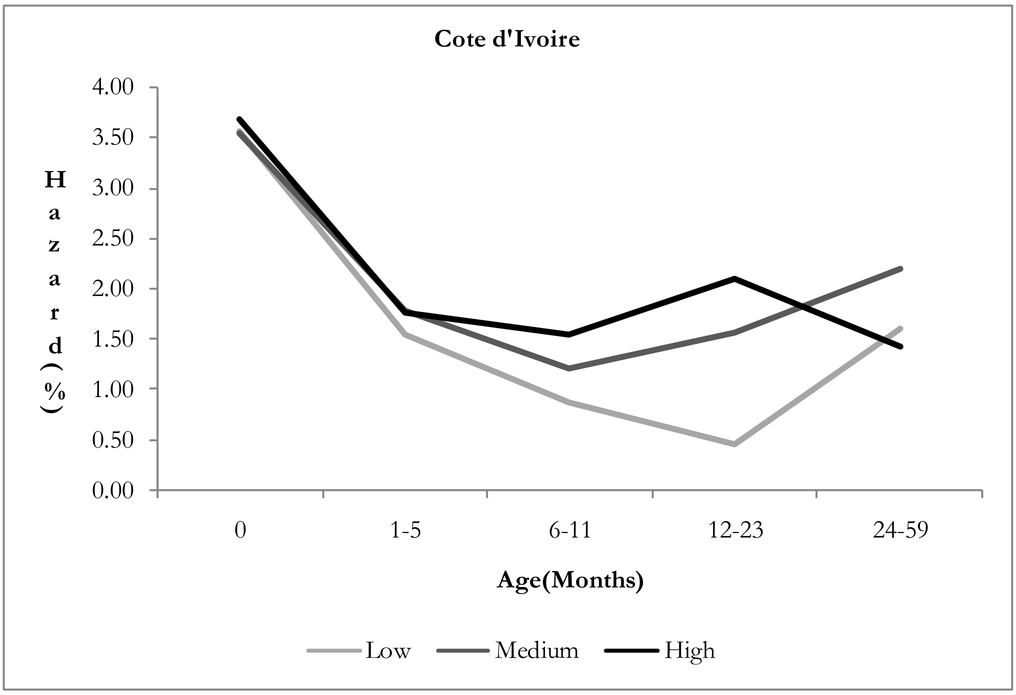
## Appendix 2. Age pattern of risk of death by level of health hazard



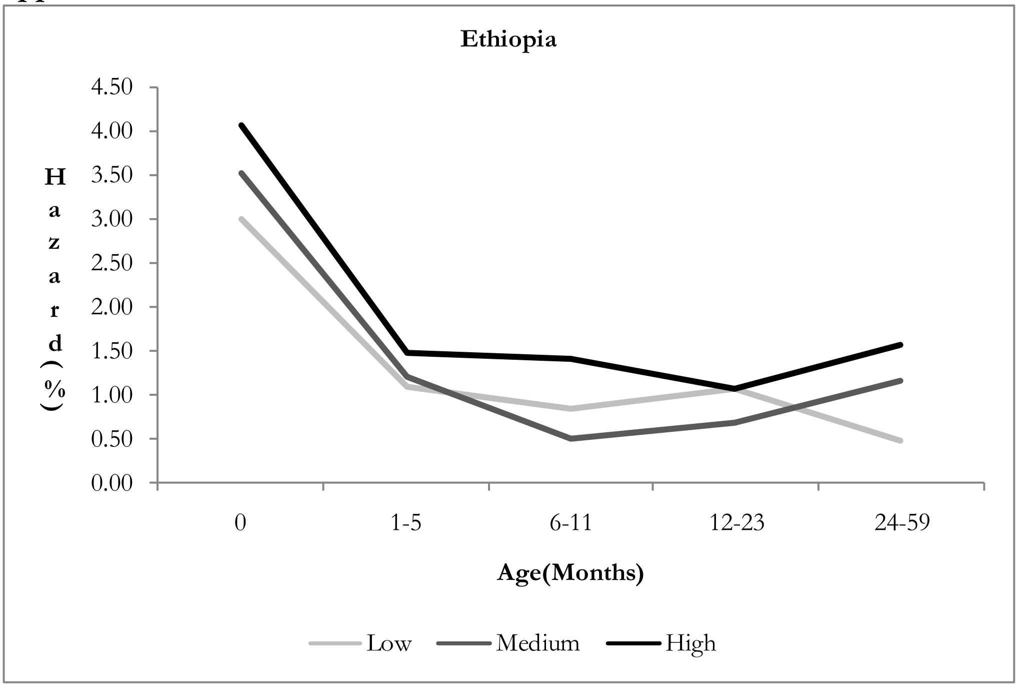



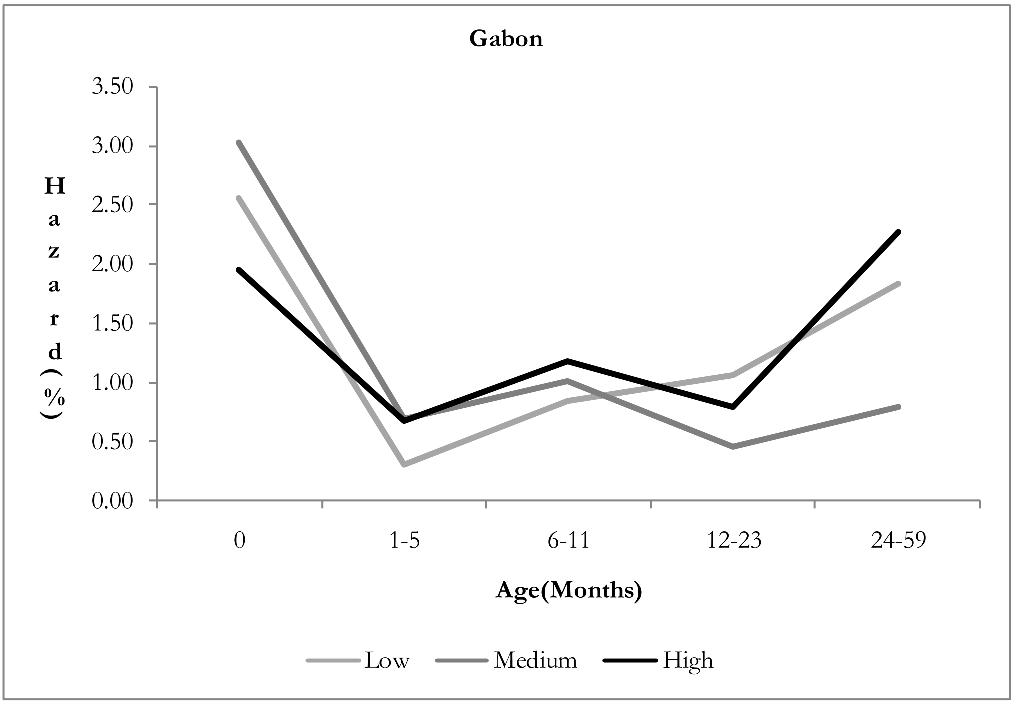
## Appendix2. Continued



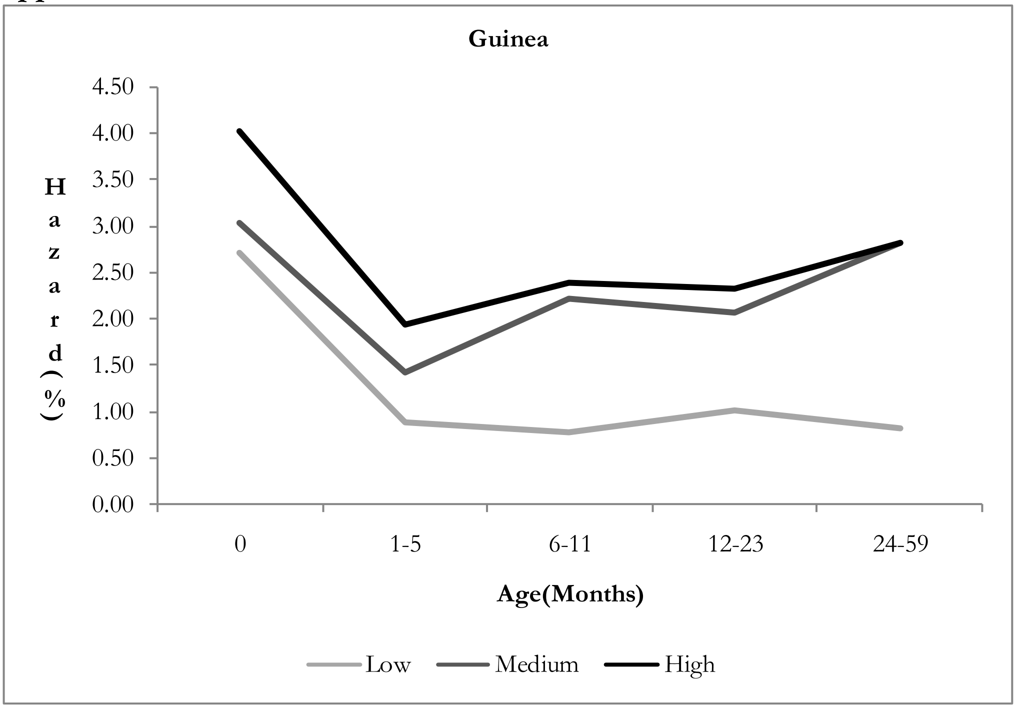



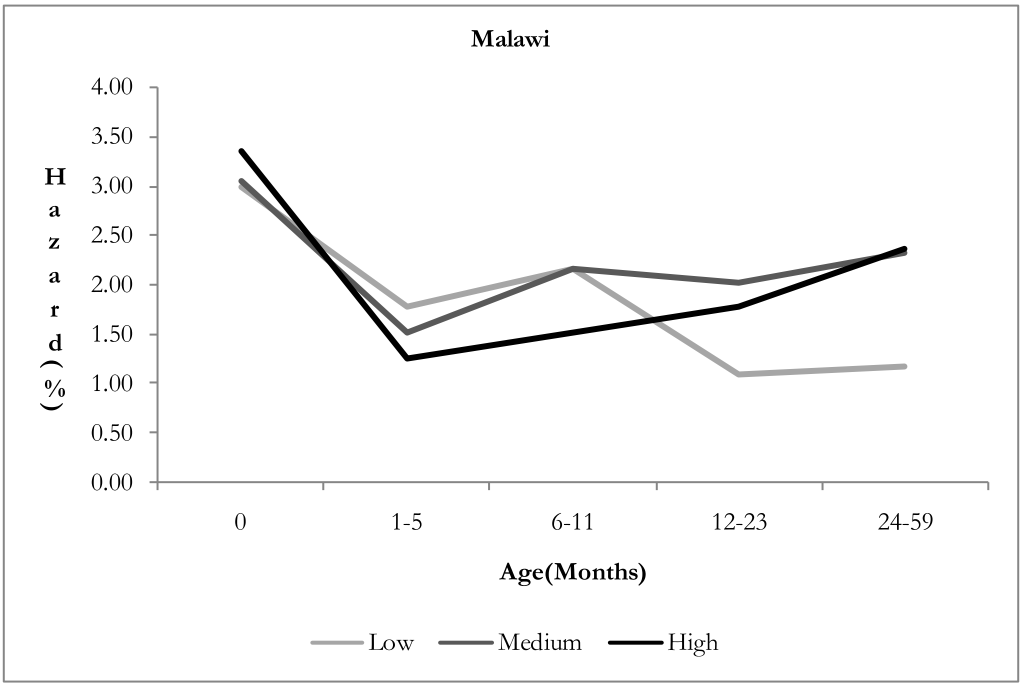
**Appendix2. Continued**



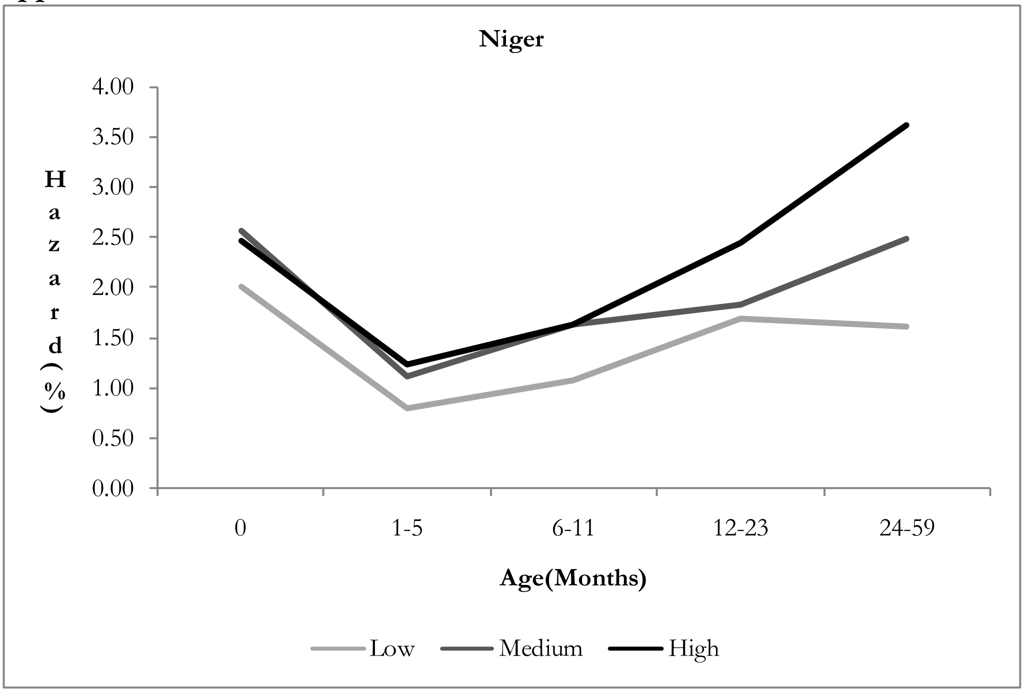



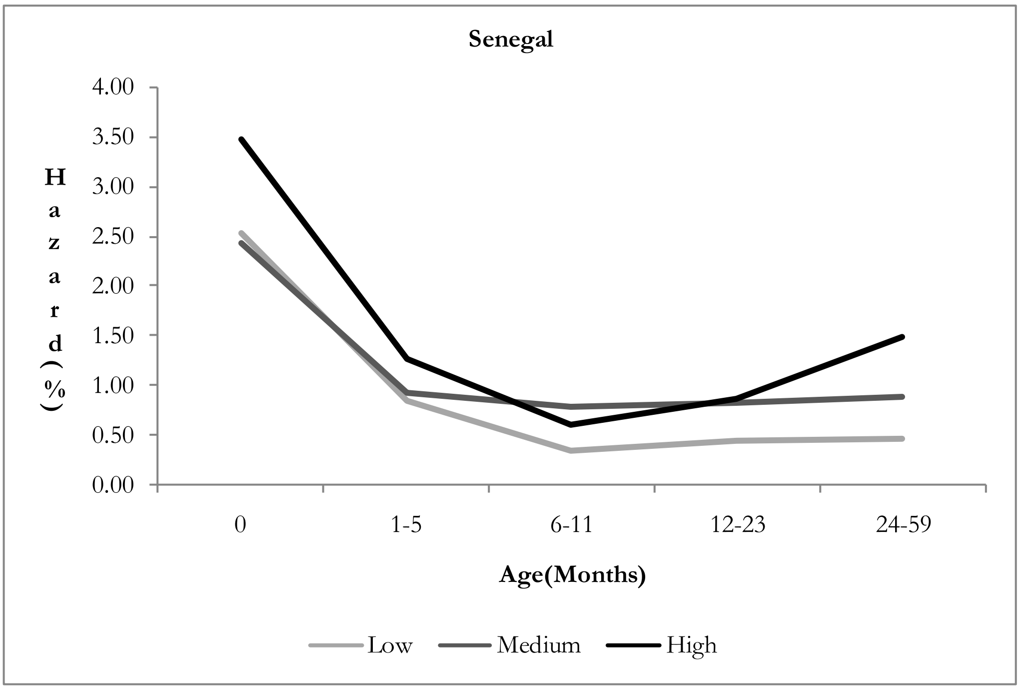
**Appendix2. Continued**



**Appendix2. Continued**



**Appendix2. Continued**