# Age Patterns of Mortality within Childhood in Sub-Saharan Africa

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# Abstract

The age pattern of mortality in sub-Saharan Africa and how it varies across the continent remain poorly understood. The region lacks accurate registration statistics and assumptions about mortality patterns are needed to produce and smooth mortality estimates. These have had to be taken from model life table systems based on non-African data.

Birth histories collected in national Demographic and Health Surveys are used to investigate age patterns of mortality in childhood in the sub-national regions of 26 countries of continental Sub-Saharan Africa. The majority of populations display a pattern of higher child relative to infant mortality than in any existing model system, including the Princeton "North" models. This reflects the existence of a "hump" of excess mortality in the late post-neonatal period and second year of life in more than three-quarters of sub-national populations. Age patterns of mortality vary markedly within and between countries, though adjacent parts of neighbouring countries sometimes have similar patterns. Particularly extreme relationships between infant and child mortality are most common in the Sahel, while a coastal belt exists adjoining the Indian Ocean with age patterns of mortality within the range of those in the Princeton models.

A three-parameter model, which incorporates this "hump", is fitted to the data using Poisson regression and fitted national life tables are produced. Except for the southwest of Africa, no extensive areas exist with homogenous parameter values for the underlying downward slope of mortality with age in childhood and the size of the "hump" respectively. Thus, the scope for construction of "regional" childhood mortality models is limited. Nevertheless, age patterns of mortality in African populations tend to share features that differ from those of historical Western populations. Thus, using the national and regional average life tables in the indirect estimation of under-5 mortality yields more consistent series of estimates than are obtained using existing models.

*To the memory of*

*the millions of African children*

*who did not live to celebrate their fifth birthdays.*

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# Chapter 1

# Introduction

## 1.1 Background

In the history of mankind, only the last two centuries has seen much change in the pattern of mortality (Cairn, 1997). In the two-hundred-year period up to the late twentieth century, the world witnessed a massive decline in mortality levels, a significant shift from communicable to non-communicable causes of death and an acceleration in population growth in an epidemiological-demographic transition which has become a global phenomenon (Mercer, 1990). However, the processes of mortality and epidemiological transition have occurred at different rates in different regions of the world. Whilst present-day industrialised countries have extremely low levels of mortality in general, infectious and communicable diseases still account for much of the relatively higher mortality at all ages in the developing world. As a result, the contemporary world has become characterised by massive mortality differentials between developed and developing countries and between and within developing Third World countries.

Attempts have been made from different perspectives to explain the factors responsible for mortality decline from extremely high to relatively low levels in both pre-industrial Europe and present Third World countries. The debate has mainly involved two camps, viz.: the advocates of improved nutritional status resulting from advances in economic development and improved living standards (McKeown and Record, 1962), and those who favour the impact of public health technology (van de Walle, 1985 cited in Vallin, 1992). In the context of the contemporary world, the rate of decline of mortality has been slower in Sub-Saharan Africa than elsewhere (Timaeus, 1999), but this decline has been faster than those registered by historical European populations during their transitions from high to low mortality levels. Thus, living conditions and income are regarded to be of greater importance in explaining the pre-industrial European transition than in the experience of Sub-Saharan Africa; while medicine, on the other hand, is considered a more influential factor in Sub-Saharan Africa's mortality transition than was the case of pre-industrial Europe. Whatever the factors during mortality transitions, currently available information shows that Africa is the world region where mortality is highest, and that it is seriously lagging in its drive to attain reasonable levels according to world standards. This predicament necessitates a meticulous approach towards the examination of the nature and major determinants of the observed mortality situation in the continent. Unfortunately, efforts at this are largely frustrated by the acute scarcity of reliable demographic data in almost the whole continent.

Infant mortality has been considered an indicator that not only describes mortality conditions in a community, but can also be used as a measure of health progress, as well as one of overall social and economic well-being. Researchers, however, have increasingly emphasised the need to examine child mortality (i.e. deaths between exact ages 1 and 5) alongside infant mortality in developing countries on the basis that:

- child mortality is still high in many such populations — higher than usual in some cases — to the extent that using infant mortality alone as an indicator of mortality will give an impression of a level of overall childhood mortality significantly lower than what actually prevails;

- the causes of death among children between the exact ages 1 and 5 are significantly different from those that prevail in infancy, suggesting that health intervention programmes for reducing infant mortality may not necessarily be effective in the reduction of child mortality (United Nations, 1983, 1988; Sambisa, 1994).

This implies that the pattern of mortality in childhood is an important issue for health care planners and administrators involved in the design and implementation of child survival programmes in the developing world. Sufficient knowledge of the age pattern of mortality in the first five years of life, for instance, can provide clues as to the underlying causes of mortality, thereby providing valuable information for informed health policy formulation. According to Feachem *et al.* (1991), such information can address issues relating to *whether* the health sector ought to be a priority concern; *where* problems of differing types are most severe; *which* conditions and diseases are placing the greatest burden on the population; *why* diseases occur, and *how* most efficiently and effectively to prevent disease and manage those cases that do occur.

However, reliable demographic data — especially mortality data — are a scarce resource in Sub-Saharan Africa. In instances where they are available, they usually refer to small geographical units and not representative of the national population. In other situations where they are collected for larger geographic entities, they are usually of poor quality due to recall and sampling biases. As a result, the data of the type that would shed light on the age patterns of mortality prevailing in the continent, especially from vital registration, are extremely limited. As a result, the continent has become heavily dependent on indirect methods of measuring mortality levels in national and sub-national populations which use models of the age pattern typical of countries at their approximate mortality level, i.e. model life tables (Preston *et al*., 1993). This is especially so in the determination of national and sub-national levels of ${}_5q_0$ using Brass's (1964) technique.

Existing model life tables are based on empirical mortality experiences of historical populations whose environments, ways of life, and — perhaps of greater significance — cause-of-death structures differ significantly from those of contemporary Africa, should one expect African populations to manifest similar mortality characteristics, especially as regards the age pattern between birth and age 5 years?

The work of Cantrelle and Leridon (1971) as far back as the early 1970s was the first to provide evidence of the existence of an unusual pattern of mortality in childhood in a rural community in Senegal. It is characterised by high child mortality relative to infant mortality. Hill *et al*. (1983) reported similar patterns of mortality in childhood in rural Mali to those documented by Cantrelle and Leridon in neighbouring Senegal. Moreover, they noted that the pattern of mortality between birth and age 5 years varied among different ethnic groups residing in the same as well as in different parts of Mali. Since such a pattern was completely different from those depicted in existing model life table systems, it became apparent that indirect estimation procedures, especially those pertaining to ${}_5q_0$, could be affected considerably as demonstrated by Garenne (1982) and Pison and Langaney (1985). The extent to which these unusual patterns of childhood mortality prevail in the continent has not been properly documented, although studies by Blacker *et al*. (1985) and Hill (1995) assert that they are more prevalent in Western Africa than other parts of the continent.

The majority of approaches to the estimation of life expectancy and other life table measures for sub-Saharan African countries require the utilisation of models of age patterns of mortality. Thus, one cannot but conclude that a need exists for models based on observed mortality experiences within the continent.

Figure 1.1 attempts to summarise the various socio-economic and environmental factors that have been linked to mortality in the vast literature, and tries to show how such factors as ethnic affiliation and conditions of the immediate environment relate to the study of African mortality. Different ethnic groups in Sub-Saharan Africa are known to have different cultures and traditional beliefs and practices that influence their ways of life in general, and health risks in particular. It is apparent from the framework, therefore, that differences in ethnic affiliation and region of residence are likely to result in differentials in mortality levels, and probably in age patterns of mortality. Although the scope of this study does not include the dynamics of how the various socio-economic and environmental factors operate through these two key classificatory variables to affect mortality of a given population, their relevance is implied in the search for homogeneity among sub-national populations in Sub-Saharan Africa. As a result, a homogeneous population can be taken to constitute a group of individuals of the same ethnic affiliation who reside in a specific geographical area. The nationally defined regions of residence stated in the respective Demographic and Health Surveys will be taken to represent such geographical units.

However, Sub-Saharan Africa is ethnically diverse to the point that inclusion of the variable “ethnicity” in research covering large geographical areas of the continent yields potentially uninterpretable or meaningless results. Since a number of ethnic groups may reside in the same sub-national region, more than one defined homogeneous population may be found in the same geographical unit, making mappings of the distribution of prevailing childhood mortality patterns cumbersome and difficult to interpret. In contrast, in sub-national regions where one or more minority ethnic groups are found in a region, the target population, i.e. children of that ethnic group residing in the region, will be relatively few in number with too few deaths to yield meaningful results in the estimation of mortality. Since the ultimate aim is to understand mortality patterns of geographical entities, it is reasonable to concentrate on the population of regions in their entirety rather than attempting to understand the demographic

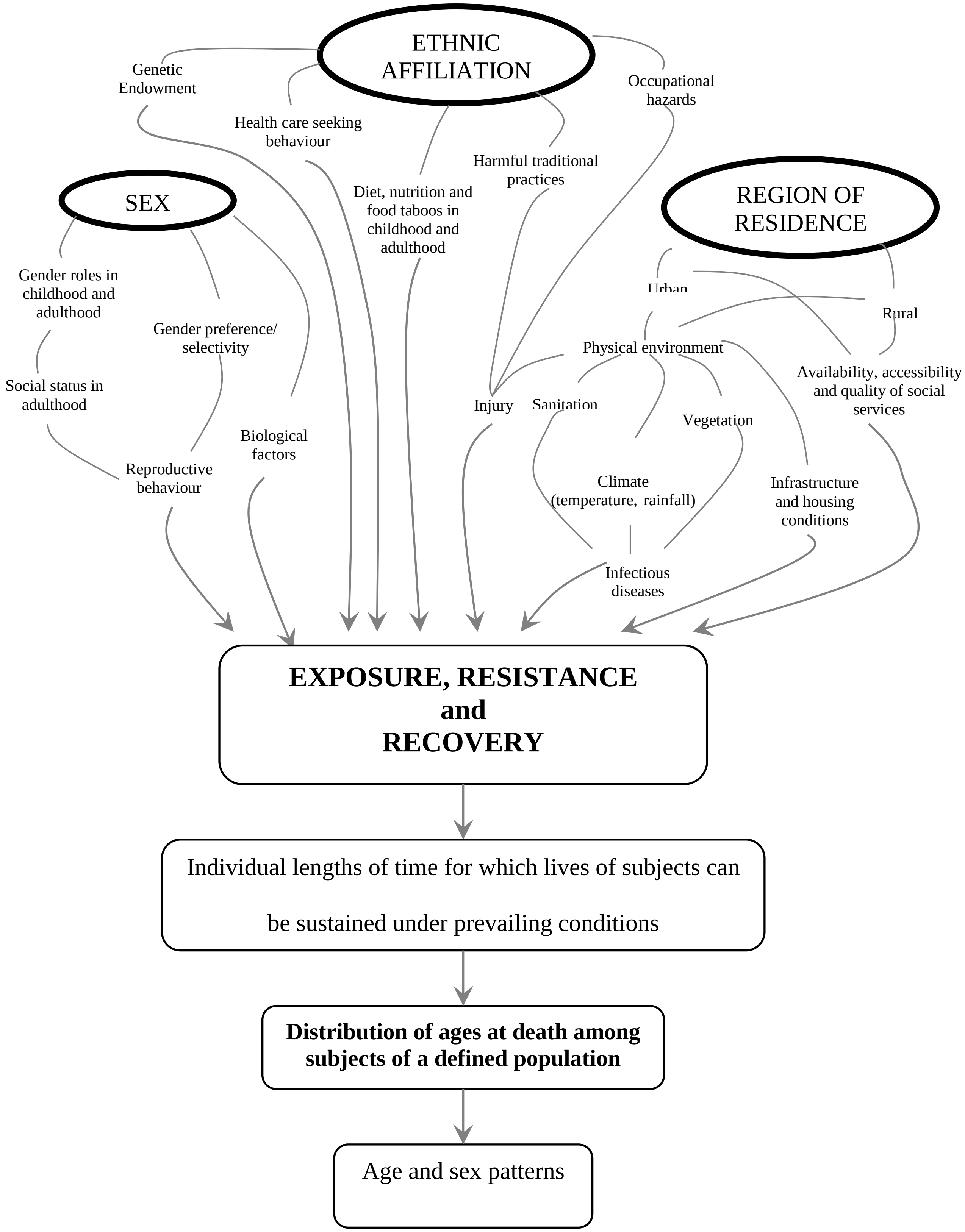



**Figure 1.1:** ***Conceptual Framework of defined sub-national populations and mortality pattern in Sub-Saharan Africa***

dynamics of their respective constituents with respect to mortality. In this regard, regions of residence will be used as indicators of the *"level of hostility"* of the environment in which the populations reside. In many instances, sub-national and international boundaries coincide with physical features such as rivers, streams, mountain ranges, etc, which constitute international or national divides to populations, as well as dictate the economic activities on which their means of survival will be based. As a result, the basic concept underlying the relationship between population homogeneity and age patterns of mortality is simplified as in Figure 1.2.

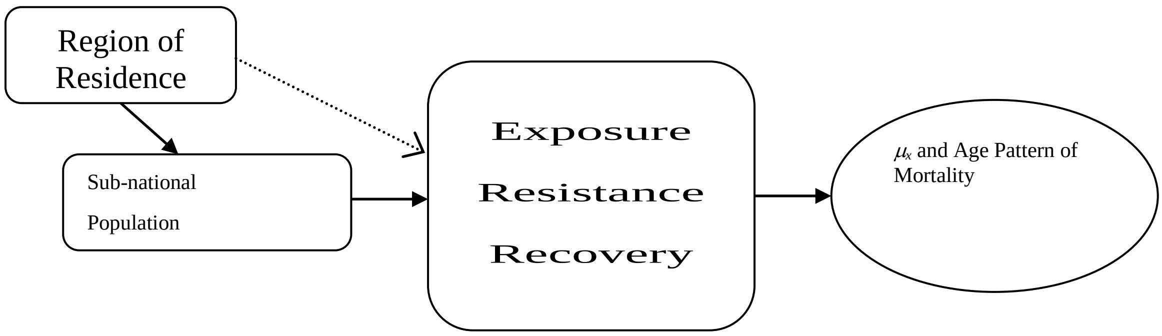



**Figure 1.2:** ***Simplified conceptual framework of homogeneous populations and mortality pattern in Sub-Saharan Africa.***

Using clusters of sub-national populations defined only by region of residence according to the official national demarcations of administrative regions[1], this study intends to identify and classify the range of age patterns of mortality in childhood observed in Sub-Saharan Africa over the last three decades of the twentieth century with a view to representing them in life tables using an existing model pattern as standard. The constituents of the proposed definition of populations to be used as unit of analysis will to a large extent control for the environmental, socio-cultural and economic diversity and heterogeneity of the continent.

[1] These "regions" are as defined in the national Demographic and Health Survey protocols.

## 1.2 Objectives

The overall goal of this study is to document and improve understanding of the patterns of mortality prevailing within childhood in Sub-Saharan Africa in the last three decades of the twentieth century. Specifically, the study endeavours to:

a. Describe patterns of mortality in childhood in Sub-Saharan Africa and their geographical distribution across the continent irrespective of international political boundaries;

b. Document the unusual features of the childhood mortality patterns observed in the continent and determine how these peculiarities render African mortality patterns different from those of existing model life table systems;

c. Represent childhood mortality in smoothed life tables for national and sub-national populations in Sub-Saharan African;

d. Explore the prospects of deriving new African mortality standards.

Achieving these objectives will contribute towards demographers' knowledge of the complexities of mortality patterns in Sub-Saharan Africa. In particular, better understanding of the distribution of various patterns of mortality in childhood across the continent will constitute an effective analytical tool in demographers' efforts towards achieving more reliable estimates of demographic measures for planning and policy formulation and implementation purposes.

## 1.3 Data and Geographical Coverage

Mortality data from Demographic and Health Surveys (DHS) constitute the bulk of the information used in this study. Although data relevant for mortality analysis are collected in such surveys at various levels (see Sullivan, 1990), this study uses only data collected at the personal level from an individual female respondent. A complete birth history is obtained from each woman together with the survival status of each child at the time of the survey, and age at death in the case of dead children. Such information facilitate direct estimation of child mortality measures for specified periods before the survey, and indirect estimation of under-five mortality levels and trend over about a fifteen-year period prior to the survey using the Brass technique.

A total of 59 national DHS surveys were conducted and completed in 31 continental Sub-Saharan African countries between 1986 and 2001. The only criterion for the inclusion of a dataset in this study was its availability as at end of 2001. Thirteen national survey datasets were not available and therefore not included in the study. This batch includes the first ever Demographic and Health Surveys for Gabon and Mauritania completed in 2000 and 2001 respectively; and eight other surveys in countries where at least one survey had been undertaken previously. These are Senegal 1999; Mali 2001; Côte d'Ivoire 1998/99; Benin 2001; Uganda 2000/01; Rwanda 2000; Malawi 2000; and Namibia 2000. The Sudanese 1990 DHS was dropped because the survey was restricted to the northern part of the country where the population identify themselves more as North African than as belonging to Sub-Saharan Africa. The survey of Ondo State in Nigeria conducted in 1986 was also excluded because it is not representative of the whole country. Access to the surveys of Botswana 1988 and Eritrea 1995 is restricted and they were not available for inclusion in the analysis. However, national mortality indicators from the respective survey reports are included in the exploratory phase of the search for childhood mortality patterns in the continent.

As a result, 44 datasets obtained between 1986 and 2001 from 26 continental Sub-Saharan African countries are included in the study and are shown in Table 1.1 by sub-region of the continent, DHS phase and year of survey. Since the surveys were representative of their respective national populations, the samples of the sub-national populations to be considered in the study are in the same token assumed to be representative of the defined sub-national populations of interest. However, the distribution of the resulting error that may originate from recall bias cannot be established.

**Table 1.1:** ***National Demographic and Health Surveys selected for inclusion in the study.***

| **Country** | **DHS Round & Year of Survey** | | | |
|---|---|---|---|---|
| | **I** | **II** | **III** | **IV** |
| ***Sahel West Africa*** | | | | |
| Senegal | 1986 | 1992 | 1997 | |
| Mali | 1987 | | 1996 | |
| Burkina Faso | | 1992 | 1998 | |
| Niger | | 1992 | 1998 | |
| ***Coastal West Africa*** | | | | |
| Guinea | | | | 1999 |
| Liberia | 1986 | | | |
| Côte d'Ivoire | | | 1994 | |
| Ghana | 1988 | 1993 | | 1998 |
| Togo | 1988 | | 1998 | |
| Benin | | | 1996 | |
| Nigeria | | 1990 | | 1999 |
| ***Middle Africa*** | | | | |
| Central African Republic | | | 1994 | |
| Chad | | | 1996 | |
| Cameroon | | 1991 | 1998 | |
| ***East Africa*** | | | | |
| Uganda | 1988 | | 1995 | |
| Kenya | 1989 | 1993 | 1998 | |
| Tanzania | | 1992 | 1996 | 1999 |
| Rwanda | | 1992 | | |
| Burundi | 1987 | | | |
| Ethiopia | | | | 2000 |
| Eritrea† | | | 1995 | |
| ***Southern Africa*** | | | | |
| Zambia | | 1992 | 1996 | |
| Malawi | | 1992 | | |
| Zimbabwe | 1988 | | 1994 | 1999 |
| Mozambique | | | 1997 | |
| Namibia | | 1992 | | |
| Botswana† | 1988 | | | |
| South Africa | | | 1998 | |

† *Complete datasets were not available at the time of the analysis. These countries are therefore restricted in the first part of the exploratory analysis only using national mortality indicators.*

The distribution by continental sub-region indicates the inclusion of 9 surveys from the Sahel West Africa; 11 from Coastal West Africa; 4 from Middle Africa; 11 from Eastern Africa; and 7 from Southern Africa. Although Middle Africa constitutes a vast geographical area, a DHS-type survey has not yet been conducted in the Democratic Republic of Congo, which covers almost half of Middle Africa. In terms of sub-regional representation by time of survey, every sub-region has at least one survey from each of the three rounds included, except for Middle Africa in the first round.

In addition to DHS data, census data are used to serve as supplementary information in the analysis of levels and trends in childhood mortality to cross-check and validate DHS-based results for the countries concerned. These include the censuses of Mali, 1987; Liberia, 1974; Côte d'Ivoire, 1988; Central African Republic, 1975; Uganda, 1969 and 1991; Kenya, 1962, 1969, 1979 and 1989; Rwanda, 1981; Zambia, 1969 and 1990; Zimbabwe, 1992; and Namibia, 1991.

The countries selected for inclusion in the study by virtue of the availability of at least one national DHS dataset cover two politically contiguous geographic regions across the continent (see Figure 1.3). These are Western and Middle African countries on the one hand, and Eastern and Southern African countries on the other. This enhances cross-border as well as continental sub-regional comparisons of mortality indicators and characteristics, especially through cartographic presentation. Individual country maps showing the sub-national regions used in this study are presented in Appendix 1. In order to guide the analysis and structure the presentation of results in the ensuing chapters, the countries included in the study are divided into five groups depicting the main sub-regions of the continent. The groups and their respective constituent countries are:

i. ***Sahel West Africa***: Senegal, Mali, Burkina Faso and Niger;
ii. ***Coastal West Africa***: Guinea, Liberia, Côte d'Ivoire, Ghana, Togo, Benin and Nigeria;
iii. ***Middle Africa***: Cameroon, Central African Republic and Chad;
iv. ***Eastern Africa***: Kenya, Tanzania, Uganda, Rwanda, Burundi and Ethiopia; and
v. ***Southern Africa***: Zambia, Malawi, Mozambique, Zimbabwe, Namibia and South Africa.

It must be pointed out that the groups are not in any way a socio-economic or political classification of the countries concerned and do not represent of different mortality regimes.

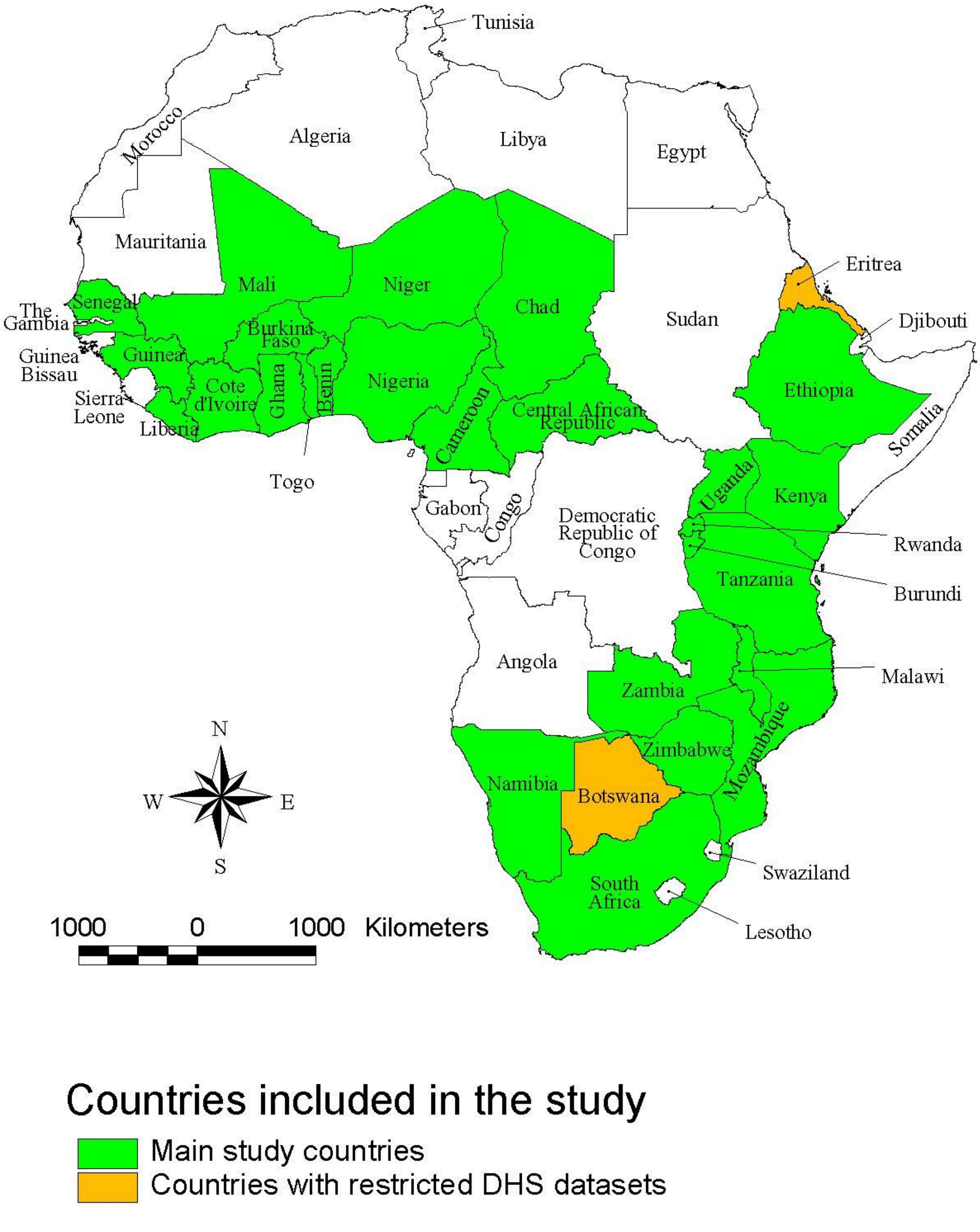



**Figure 1.3:** ***Geographical distribution of countries included in the study***

## 1.4 Thesis Outline

This thesis is presented in nine chapters including this introductory one. **Chapter 2** reviews demographers' state of knowledge regarding mortality in Sub-Saharan Africa in general, and in childhood in particular. It highlights the constraints posed by scarcity and paucity of reliable mortality data that hinder a better understanding of the patterns of mortality prevalent in the continent. It also outlines advances made in data collection approaches and estimation methods that have enabled demographers to fill some of the knowledge gaps with respect to mortality in the continent, especially levels of childhood mortality. The chapter details out the limited knowledge of the types and distribution of prevalent mortality patterns in childhood across the continent, as well as the implications of the unfolding HIV/AIDS epidemic. **Chapter 3** reviews the underlying concepts, evolution and modes of construction of the main model life table systems, outlining their respective advantages and disadvantages as they pertain to the study of Sub-Saharan African mortality in childhood. The chapter also attempts a critical comparison of the model life table systems with a view to identifying the most suitable system to adopt in the exploration of childhood mortality patterns in Sub-Saharan Africa.

In **Chapter 4**, the quality of the data used in this study is assessed using internal and external consistency checks. Recent estimates of national childhood mortality indicators are directly derived from the respective national DHS surveys; and trends from both direct and indirect estimates of ${}_5q_0$ presented to provide a complete geographical distribution of childhood mortality levels over time across the continent. Using infant (${}_1q_0$) and child (${}_4q_1$) mortality estimates, **Chapter 5** presents the results of a graphical exploration that identifies the types of childhood mortality patterns that prevail in national and sub-national populations respectively. Their respective distinctive characteristics are documented, and their geographical distributions over time are explored by mapping them. The chapter also attempts to determine whether the distribution of identified patterns of mortality is constrained by international political boundaries, or whether they also cluster into contiguous geographic units comprised of sub-national regions of different adjacent countries.

On the basis of the discovery that the childhood mortality patterns observed in two-thirds of sub-national regions of the 26 countries considered fall outside the range of the Princeton system, an in-depth assessment of the age-specific mortality schedules in childhood prevailing in the continent is undertaken in **Chapter 6**. The characteristics of the detailed childhood mortality schedules are examined and their implications for the aggregate measures of ${}_1q_0$ and ${}_4q_1$ assessed to determine whether they are responsible for the unusual mortality patterns observed in national and sub-national populations of the continent. Excess mortality in the post-neonatal period and second year is found to be widely prevalent in all parts of the continent. This feature of the mortality schedule in childhood is then included as an integral component of a three-parameter relational model that is formulated in **Chapter 7** and fitted to all national and sub-national data to describe the trend and pattern of childhood mortality over time. The analysis also aims at determining whether controlling for the "hump" of excess mortality yields underlying childhood mortality patterns within or close to the Princeton range.

From the results of the fitted national models, national life tables are derived in **Chapter 8** to represent the changing pattern of mortality in childhood over time in the countries included in the study that adequately reflect the unusual features of mortality in the first two years of life. On the basis of sample application of selected national life tables, the chapter explores the prospects of devising new African mortality standards for defined geographic regions of the continent. The main findings of the study are summarised in the conclusions presented in **Chapter 9**. Their significance and contribution to demographers' knowledge of childhood mortality in Sub-Saharan Africa are evaluated, and their implications for further research are assessed.

# Chapter 2

# Childhood Mortality in Sub-Saharan Africa: Demographers' State of Knowledge[2]

## 2.1 Introduction

As in any world region, the study of mortality in Sub-Saharan Africa is relevant for the formulation and evaluation of social and economic policies geared towards the improvement of quality of life and longevity among the continent's diverse populations. In fact, childhood mortality, and infant mortality in particular, is conventionally used as a broad indicator of social development and as a more specific indicator of health status (Hill, 1991b). Measures of it are vital in making population projections; whilst characteristics such as age pattern, socio-economic differentials, cause of death structure, and sub-national distribution, are used to investigate causal relationships and as design interventions. Moreover, information on trends at different geographic levels — for which Sub-Saharan Africa depends heavily on indirect measurement techniques — is also useful in the evaluation of the impact or efficiency of social and economic interventions.

This chapter, however, does not focus on determinants but reviews the extent to which research on Sub-Saharan African mortality in childhood has evolved over the second half of the last century, placing emphasis on methodological issues relating to data collection and measurement techniques. An assessment is also made with respect to current demands for methodological advances as more data become available from the Demographic and Health Survey programme and other sources.

## 2.2 Evolution of Childhood Mortality Research in Sub-Saharan Africa

### *2.2.1 The State of Mortality Data*

Death registers constitute the best source of information for the direct measurement of levels and patterns of mortality in any region. In the absence of such registers, or where they are too incomplete to be used for such a purpose, indirect techniques of mortality estimation can be employed. Such techniques have been developed not as a replacement for death registers, but as tools capable of producing reasonable and acceptable estimates of mortality measurements in populations characterised by the absence or incomplete death registration. No country in mainland Sub-Saharan Africa has a 100%-complete vital registration system (Hill, 1991b; Murray *et al*., 1992; Timaeus, 1999); and in most countries the cost of developing such a system would be prohibitive, even if it were possible. Coverage is mainly restricted to urban centres; and even then coverage levels for births and deaths may differ. In addition, registered events cannot be regarded as representative of all deaths in terms of socio-economic characteristics or cause-of-death structure. Delayed registration as well as failure to publish the information collected, which are very common in Sub-Saharan African countries, can also limit the value of such vital registration data. Even when perfect, vital registration data have limited scope for in-depth mortality analysis because of the limited amount of socio-economic data collected. As a result, and because of the inadequacy of African vital registration systems in terms of coverage and errors emanating from age misreporting, the information collected can hardly be used for meaningful national mortality studies.

Against this background, the major sources of data for the measurement of mortality in sub-Saharan Africa are censuses, single and multi-round surveys, and surveillance systems. Although these sources produce a range of data types appropriate for use with specific techniques for the estimation of child and adult mortality depending on the types of question asked, they do come with disadvantages. In most Sub-Saharan African countries, the censuses conducted in the second half of the twentieth century occurred at intervals of at least 10 years, and were published about 3-4 years after the enumeration. Such delays render direct mortality measures from censuses quite untimely. Moreover, intercensal periods are characterised by little or no directly estimated mortality indicators. By virtue of their expensive and intensive nature, multi-round surveys and surveillance systems in Sub-Saharan African cover extremely small areas or small sub-national populations. (Few nationally representative multi-round surveys have been conducted recently using clustered designs.) Although they yield high quality data and offer excellent opportunities for detailed research, they are not capable of producing nationally representative demographic measures and also have to be maintained for extremely long periods in order to yield reliable information on trends in demographic indicators (Hill, 1991b).

From the early 1980s, however, the World Fertility Survey (WFS) and Demographic and Health Surveys (DHS) programmes made possible direct estimation of child mortality indicators from birth history data. In these surveys, a complete birth history is obtained from individual female respondents aged between 15 and 49 years together with information on the survival of each child at the time of the survey, and the age at death in the case of dead children. Such information enables direct calculation of age-specific probabilities of death between birth and age five years for specified periods prior to the survey, including all the conventional childhood mortality indicators viz.: neonatal, post neonatal, infant, child and under-five mortality rates (see Sullivan, 1990; Boerma and Sommerfelt, 1993). While they fulfil many requirements for childhood mortality research in Sub-Saharan Africa, birth histories are fairly expensive and usually available only for limited sample sizes. Another limitation of such data is the potential reporting and recall biases they are subject to. However, evaluations of DHS data quality have shown that questions involving potential sources of error are reasonably well reported; and omission of births and deaths is generally within limits (Sullivan *et al*., 1990; Boerma and Sommerfelt, 1993). Hill (1991b) gives detailed descriptions of these data types, together with the respective methods with which they are used for child mortality estimation and discusses their limitations. He arrives at the conclusion that no single data collection or analysis method meets all the needs for measures of child mortality.

Despite these developments in the collection of mortality data during the last two decades, Sub-Saharan Africa continues to be characterised by scarcity and paucity of reliable mortality data and estimates of levels and trends of mortality in Africa remain subject to some degree of uncertainty (Ewbank, 1990). Coupled with the fact that the distribution of the causes of morbidity and mortality both in childhood and adulthood throughout the region is poorly understood (Feachem *et al*., 1991), this renders the study of African mortality an inexact science very much in need of methodological advances in estimation techniques.

### *2.2.2 Methodological Issues: Measurement and Analytical Procedures*

Using the proportion of mortality-related articles published in Population Studies between 1950 and 1985 as a rather crude indicator, Hobcraft (1987) showed that the relative importance of the field of mortality research reached its lowest ebb around the time the

Princeton Model Life Tables were produced in 1966 (Coale and Demeny, 1966), and only started regaining its standing from the early 1970s. The period covering the mid-1960s and early 1970s witnessed the introduction of Brass's (1964) indirect technique[2] of childhood mortality estimation using aggregate numbers of children ever borne and proportions dead by age of mother. This was followed by modifications through the works of Sullivan (1972) and Trussell (1975) aimed at increasing the flexibility of the method (see United Nations, 1983). The renewed interest in the study of mortality from the latter part of the 1970s was partly due to the excitement brought about by indirect estimation techniques, and partly to rejuvenated intellectual debate dominated by demographers' concerns regarding the appropriateness of existing model life table systems based on the mortality experiences of developed societies for estimation of mortality in developing countries. The next chapter explores this issue.

Following general acceptance and wide use of the indirect techniques soon after their introduction, bilateral organisations such as the United Nations made considerable efforts to encourage developing countries to incorporate the relevant Brass questions into subsequent censuses and surveys. As a result, the nature of mortality research in the developing world became completely transformed (Hobcraft, 1987). Some aspects of the mortality situation in Sub-Saharan Africa became clarified, but this raised significant questions regarding the social and economic differentials and determinants of child survival across the continent. These issues dominated the research agenda with respect to mortality in Sub-Saharan Africa for the two decades following the introduction of indirect techniques of mortality measurement (Hobcraft, 1987). This is also the period that witnessed improvements in the methods of data collection — such as birth histories in the WFS and DHS — and the introduction of new statistical modelling approaches that attempt to relate mortality differentials to a range of social, cultural and economic factors (Sullivan, 1990). But, given the paucity as well as scarcity of demographic data that continues to characterise the continent, the "Brass" questions — given their low cost — were undoubtedly beneficial for Sub-Saharan Africa despite the fact that they only yield smoothed estimates of trends in ${}_5q_0$, and absolutely little information or nothing at all on biosocial differentials or age patterns of mortality.

[2] The fundamental principle on which the method is based is explored in detail in Chapter 4.

Further developments to the Brass method the include work of Preston and Palloni (1977), Palloni (1980) and Feeney (1980). Preston and Palloni cited the following as possible sources of error in Brass-type estimates of mortality:

- Incomplete and inaccurate reporting of the numbers of dead and surviving children.
- Errors introduced by fertility trends;
- Lack of closure of groups of reporting women;
- Misstatement of women's ages;
- Uncertainty about the appropriate model mortality pattern and mortality trends.

They believed that the amount of error due from each source could be minimised or neutralised by improved techniques of analysis.

Garenne (1982) demonstrated the problems likely to be encountered when applying Brass's method to data from Sub-Saharan Africa. These problems include an unexpected age pattern of mortality, age misstatement and under-reporting of early deaths. He compared direct estimates of infant and child mortality obtained from reliable multi-round demographic survey from communities in rural Senegal with indirect estimates using the relevant information and the Princeton "North" model pattern as standard. The disparities between the sets of estimates were very significant and led him to arrive at two conclusions:

- The observed age patterns of mortality in the two communities were completely different from the "North" model;

- The indirect estimates obtained were inaccurate to the point that the original information on proportions dead of children ever born provided a better indication of the level of childhood mortality.

One issue that is of great relevance to the discipline of mortality research in Sub-Saharan Africa, therefore, is the construction of suitable model life tables that adequately represent prevailing patterns of mortality in the continent. Attempts to derive life tables to reflect the mortality situation of specific communities or areas are not frequent, probably due to the scarcity of relevant data of the highest quality. However, Pison and Langaney (1985) used multi-round survey data from Bandafassi in south-eastern Senegal to construct a life table for the area. Because of the dire situation surrounding demographic data in other parts of West African and the continent at large during that period, they wondered whether the life table for Bandafassi could be regarded as a model. However, they hasten to caution that the high level of mortality observed may not necessarily prevail in other African populations.

### *2.2.3 Usefulness of Model Life Table Systems*

As Cantrelle (1972) hinted, since the Princeton Regional Model Life Tables are based on different observed mortality patterns that approximate to geographical groupings of European origin, there is reason to suggest that as sufficient and accurate data become available from other regions — especially from tropical populations — other mortality patterns would emerge. From the World Fertility Survey and the first round of the Demographic and Health Survey Programme, as well as longitudinal and national demographic surveys carried out in many African countries, indications emerged that African populations present a myriad of age patterns of mortality, especially in childhood. For instance, Blacker *et al*. (1985) emphasised that mortality in Africa between the ages one and five is often higher, relative to infant mortality, than even in the "North" family of the Princeton Model system. Furthermore, the "East" family provides the best average fit to child and adult mortality for African populations but manifests a pattern of childhood mortality that is very different from what has been observed in much of Sub-Saharan Africa. However, the extent to which these assertions are the demographic reality in the continent — in terms of range of prevailing patterns and geographical distribution — is yet to be established.

Notwithstanding, similar viewpoints emanated from different studies to show that neither the Princeton nor the New United Nations Model Life Tables adequately describe all African mortality patterns (see Blacker *et al*., 1985; Bicego and Ahmad, 1996). In fact, Bicego and Ahmad (1996) concluded that at ${}_5q_0$ levels in excess of 100 per 1,000, the age patterns of childhood mortality described in the Princeton Model Life Tables do not reflect the actual mortality conditions occurring in most of sub-Saharan Africa. Further complicating the situation is the observation by Blacker *et al*. (1985) that characteristics of age-specific mortality schedules of different African populations are not associated with their overall level of mortality or with their geographical location within the continent. As a result, age patterns of mortality have been observed to differ not only between large populations, but also between different ethnic groups living in the same geographical area (Hill *et al.*, 1983). This contrasts with the earlier general contention that populations in close proximity with each other may display similar mortality patterns, thereby suggesting the need for a systematic assessment of the mortality experiences of various sub-national populations, with a view to identifying the essential determinants of age patterns of mortality in sub-Saharan Africa.

## 2.3 Documented Levels and Trends in Childhood Mortality

One of the more concise expositions of demographers' state of knowledge with respect to infant and child mortality in Sub-Saharan Africa in relation to social and environmental factors is that given by Blacker (1991). In more recent periods, detailed investigations have been carried out focussing on various determinants of infant and child mortality as outlined by Mosley and Chen (1984) in their analytical framework for the investigation of child survival in developing countries. The World Health Organization, for instance, dedicated the 78$^{th}$ issue of its Bulletin to child mortality in the developing world. The articles included in this issue assessed how fast and where mortality is declining in the developing world, and the role of several of the proximal factors in the Mosley-Chen framework in bringing about decline (see Lopez, 2000).

Available evidence indicates that mortality in Sub-Saharan Africa is generally high by world standards and life expectancy is commensurately low. Despite significant progress made in the post-independence era, mortality and morbidity levels in Africa remain the highest in the world (Feachem *et al*., 1991; Timaeus, 1993). Until the 1960s, mortality levels in Africa were highest in the western region, with the lowest mortality countries being in the south and east (Hill, 1991a; Timaeus, 1991). However, such a pattern became less distinct in the 1970s and early 1980s when mortality dropped significantly in most West African countries, whilst stagnating in many parts of eastern and southern countries (Hill, 1993; Timaeus, 1993).

It should be noted, however, that these generalisations about African mortality hide the fact that Africa is not a homogeneous continent with uniformly higher mortality than the rest of the world as shown in Table 2.1 compiled by Ahmad *et al*. (2000). There is enough evidence

**Table 2.1:** ***Trends in 5-year estimates of national under-five mortality rates in Africa, 1970-1999, and WHO estimates for 1999.***

| Region and Country | Under-5 Mortality Rate (per 1,000) | | | | | | Estimate for 1999 | Confidence interval of '99 estimate |
|---|---|---|---|---|---|---|---|---|
| | 1970-74 | 1975-79 | 1980-84 | 1985-89 | 1990-94 | 1995-99 | | |
| **Northern Africa** | | | | | | | | |
| Algeria | 187 | 147 | 112 | 66 | 60 | 56 | 49 | 38-63 |
| Egypt | 222 | 188 | 154 | 126 | 106 | 87 | 73 | 63-84 |
| Libya | 114 | 68 | 55 | 43 | 39 | 38 | 37 | 27-49 |
| Sudan | 154 | 141 | 138 | 134 | 137 | 112 | 110 | 86-147 |
| Tunisia | 187 | 129 | 99 | 65 | 46 | 37 | 34 | 26-41 |
| ***Mean*** | ***173*** | ***135*** | ***112*** | ***87*** | ***78*** | ***66*** | ***61*** | |
| **Western Africa** | | | | | | | | |
| Benin | 250 | 222 | 202 | 186 | 172 | 157 | 153 | 134-174 |
| Burkina Faso | 271 | 252 | 230 | 207 | 183 | 180 | 177 | 151-206 |
| Côte d'Ivoire | 213 | 177 | 163 | 152 | 145 | 136 | 135 | 114-161 |
| Ghana | 179 | 164 | 151 | 138 | 120 | 116 | 114 | 95-135 |
| Guinea | 290 | 275 | 259 | 252 | 224 | 206 | 205 | 180-230 |
| Guinea Bissau | 301 | 292 | 257 | 236 | 220 | 204 | 202 | 175-236 |
| Liberia | 247 | 237 | 227 | 212 | 204 | 204 | 205 | 176-240 |
| Mali | 366 | 318 | 281 | 260 | 249 | 241 | 235 | 214-260 |
| Mauritania | 208 | 193 | 181 | 185 | 182 | 178 | 179 | 157-204 |
| Niger | 290 | 295 | 305 | 316 | 334 | 334 | 335 | 310-363 |
| Nigeria | 205 | 197 | 192 | 192 | 177 | 175 | 172 | 148-199 |
| Senegal | 273 | 237 | 197 | 163 | 145 | 130 | 130 | 114-149 |
| Sierra Leone | 350 | 341 | 336 | 327 | 320 | 316 | 312 | 271-367 |
| The Gambia | 309 | 241 | 209 | 153 | 125 | 100 | 98 | 85-114 |
| Togo | 205 | 185 | 166 | 150 | 135 | 133 | 132 | 108-161 |
| ***Mean*** | ***264*** | ***242*** | ***224*** | ***209*** | ***196*** | ***187*** | ***186*** | |
| **Middle Africa** | | | | | | | | |
| Cameroon | 203 | 193 | 160 | 135 | 130 | 125 | 122 | 106-136 |
| CAR | 216 | 196 | 178 | 163 | 160 | 150 | 148 | 129-166 |
| Chad | 272 | 252 | 226 | 204 | 191 | 174 | 175 | 143-213 |
| Congo | 135 | 130 | 128 | 120 | 112 | 108 | 107 | 89-127 |
| DRC | 231 | 215 | 205 | 191 | 178 | 164 | 162 | 141-185 |
| Gabon | 220 | 198 | 180 | 164 | 128 | 92 | 90 | 73-109 |
| ***Mean*** | ***213*** | ***197*** | ***180*** | ***163*** | ***150*** | ***136*** | ***134*** | |

**Table 2.1 — *continued.***

| Region and Country | Under-5 Mortality Rate (per 1,000) | | | | | | Estimate for 1999 | Confidence interval of '99 estimate |
|---|---|---|---|---|---|---|---|---|
| | 1970-74 | 1975-79 | 1980-84 | 1985-89 | 1990-94 | 1995-99 | | |
| **Eastern Africa** | | | | | | | | |
| Burundi | 227 | 202 | 179 | 175 | 198 | 168 | 168 | 144-197 |
| Djibouti | 243 | 202 | 196 | 193 | 184 | 170 | 166 | 147-202 |
| Eritrea | 222 | 206 | 182 | 161 | 152 | 140 | 139 | 121-159 |
| Ethiopia | 236 | 224 | 205 | 205 | 194 | 184 | 183 | 162-207 |
| Kenya | 150 | 124 | 110 | 103 | 94 | 98 | 100 | 87-112 |
| Rwanda | 216 | 226 | 213 | 182 | 230 | 190 | 176 | 149-206 |
| Somalia | 255 | 247 | 236 | 217 | 220 | 204 | 201 | 173-245 |
| Tanzania | 209 | 189 | 166 | 157 | 137 | 150 | 153 | 134-170 |
| Uganda | 174 | 184 | 184 | 202 | 197 | 165 | 159 | 142-180 |
| ***Mean*** | ***215*** | ***200*** | ***186*** | ***177*** | ***178*** | ***163*** | ***161*** | |
| **Southern Africa** | | | | | | | | |
| Angola | 285 | 265 | 246 | 228 | 207 | 205 | 201 | 173-238 |
| Lesotho | 182 | 164 | 151 | 148 | 145 | 141 | 141 | 119-164 |
| Malawi | 318 | 274 | 262 | 245 | 237 | 231 | 219 | 196-248 |
| Mozambique | 282 | 288 | 265 | 242 | 213 | 197 | 193 | 164-225 |
| South Africa | 133 | 89 | 80 | 69 | 55 | 65 | 76 | 60-92 |
| Swaziland | 191 | 148 | 131 | 108 | 90 | 100 | 102 | 85-119 |
| Zambia | 168 | 156 | 158 | 186 | 194 | 173 | 169 | 149-190 |
| Zimbabwe | 137 | 113 | 100 | 86 | 80 | 115 | 118 | 101-134 |
| ***Mean*** | ***212*** | ***187*** | ***174*** | ***164*** | ***153*** | ***153*** | ***152*** | |

***Source: Ahmad et al., 2000.***

to suggest significant variations in the levels of child and adult mortality between and within countries in much of Sub-Saharan Africa (Timaeus, 1999). In fact, with respect to child mortality, many East and Southern African countries, as well as few in West Africa, compare well with parts of the Indian sub-continent, and several countries in Latin America and the Middle East (Hill, 1991a).

Probably the best account of childhood mortality levels since the second World War is that given by Hill (1992). Focussing mainly on under-5 mortality (${}_5q_0$) in a comparative analysis and using the Brass indirect technique of ${}_5q_0$ estimation, Hill (1992) estimates that levels of

$_5q_0$ in Sahelian Western Africa ranged from about 42% in 1948 in Burkina Faso to about 28% in 1971 in Burkina Faso and Senegal. Along the West African coast, estimates ranged from about 38% in 1942 in Guinea to 20% in 1967 in Ghana, and 1974 in Côte d'Ivoire. Much lower mortality levels were observed in East and Southern Africa. A $_5q_0$ of 26% was estimated for Kenya in 1947 and one as low as about 14% in 1978 in Zimbabwe. Swaziland in the Southern part of the continent registered a level of 24% in 1951, but levels in this sub-region declined to about 12% in 1977 in Botswana (Hill, 1992).

A few countries have manifested remarkable declines in $_5q_0$ since the Second World War. For instance, the percentage of children dying before reaching age 5 almost halved in Ghana (from 37 to 20%) over 30 years between the late 1930s and late 1960s; in Congo (from 29 to 15%) over 20 years between the late 1940s and late 1960s; and in Kenya (from 26 to 15%) over 25 years between the late 1940s and early 1970s. In most other countries, declines have been much more gradual (Hill, 1992).

Hill (1992) identified four general features relating to under-5 mortality in sub-Saharan Africa, viz.:

a. an apparent general decline in $_5q_0$ in most countries where data are available since the second World War;

b. the types of decline observed vary between countries;

c. levels of $_5q_0$ vary between countries;

d. a distinct overall, but gradually narrowing, difference in levels of $_5q_0$ between eastern and western Africa, with levels being relatively lower in the eastern region.

Notwithstanding these generalistions, Hill, (1992) observed three exceptions. The first is that a few countries had static or rising mortality, e.g. Angola, Mozambique, Ethiopia, and Rwanda. Although there are doubts or reservations surrounding the observations in these countries, taking into consideration their respective political, social and economic development experiences over the past few decades, they collectively suggest that the level of childhood mortality may be sensitive to socio-political instability with accompanying interruptions or stagnation of socio-economic development. Secondly, Congo, Ghana and Cameroon in West Africa manifested declines in ${}_5q_0$ similar to those observed in some Eastern African countries. Third, Malawi in the east displayed levels of mortality that are high even by western African standards.

Several attempts have been made to explain the differentials in childhood mortality levels between national and sub-national populations. As mentioned earlier, Mosley and Chen (1984) propounded an analytical framework for investigating the determinants of child survival in the developing world. Studies in different parts of the continent have singled out ethnicity as a main socio-cultural determinant of mortality, especially in childhood (see Wenlock, 1979, for Zambia; Hill *et al.*, 1983, for Mali; Cantrelle *et al*., 1986, for Senegal; and Tabutin and Akoto, 1992, for Kenya and Cameroon). Mensch *et al*. (1985), using data dating as far back as the 1960s, categorically point out that *"ethnicity… exerts a strong influence on mortality in [African] countries where ethnic groups appear to be sharply differentiated"*. Despite these conclusions, systematic scrutiny of ethnic differentials in childhood mortality has been largely absent in the literature on African mortality. This is especially the case when it comes to postulation of theories that attempt to relate how political, economic and cultural mechanisms operate through ethnic affiliation to affect child and adult mortality across highly diverse African settings (Brockerhoff and Hewett, 1998). Notwithstanding this, Brockerhoff and Hewett (1998) attempted such scrutiny by investigating the influence of affiliation to ethnic groups that dominate national political fronts on child survival. Their results reaffirmed the existence of significant disparities between ethnic groups of the same country with respect to childhood mortality levels.

Maternal education is one of the most investigated factors in relation to childhood mortality and has consistently proved to have considerable influence on child survival, with the probability of surviving to age five being greater for children of mothers with higher levels of education. A closer look at the apparent relationship, however, compelled Cleland and Ginneken (1989) to clarify that the economic advantages associated with education account for almost a half of the overall education-child survival association.

Blacker (1991), on comparing the education-mortality relationship in Kenya and Sierra Leone, showed that despite the significant falls in mortality with increase in mothers' education in both countries, the level of mortality in each category was two to three times higher in Sierra Leone than in Kenya (see Figure 2.1). His conclusion from this apparent disparity was that *"over and above the differences in socio-economic development, basic environmental factors contribute to the mortality differentials between West and East Africa"*. The difference in disease environments between West Africa and the rest of the continent, as noted earlier, may also be a contributory factor to such a situation.

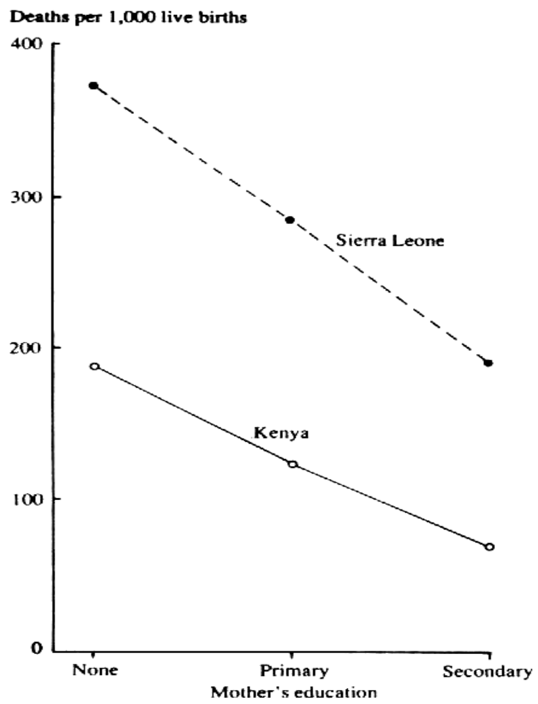



**Figure 2.1:** ***Under-five mortality rates, Sierra Leone (1974) and Kenya (1979), by mother's education.***

*Source: Blacker, 1991*

## 2.4 Disease Environments in Sub-Saharan Africa

A brief description of the disease environment and ecology in Sub-Saharan Africa — especially in relation to childhood — can enhance understanding of the levels of mortality reported for the continent. The level of infant and child mortality in any population is the result of the interaction between hazards present in the environment and the ability of the population to defend itself against those hazards.

Demographers such as Preston (1976) argue that information on causes of death, where available, is extremely valuable for programme planning and evaluation. Where such data are collected reliably, they can be used to demonstrate a causal relationship between programme inputs and mortality decline. However, even less is known about the causes of death in Sub-Saharan Africa than about mortality levels and trends since no continental Sub-Saharan

African country has a reliable national system of death registration (Ewbank and Gribble 1993). Interpretation of the little information available on causes of death in Sub-Saharan Africa is hampered by:

i. Instances of multiple causes of death, which are prevalent among deaths in childhood;

ii. Quality, or more specifically, the accuracy of diagnoses. This is a problem in even the best hospitals in the developed world.

Nevertheless, we do know the alarming magnitude of childhood mortality in less developed countries shown by demographers early in the second half of the twentieth century, which epidemiologists attributed to a few communicable diseases, triggered action geared towards the improvement of child health (Cantrelle *et al*., 1978; Blacker, 1991; Timaeus, 1991; 1993). These diseases are malaria, diarrhoea, acute respiratory infections, measles, malnutrition, and tetanus (Boerma, 1986 cited in Blacker, 1991). The grim situation portrayed necessitated the formulation and implementation of policies and strategies for improving children's health and survival in all developing countries by immunising against selected diseases, reducing exposure to environmental and behavioural risk factors, and promoting selected cost-effective approaches to case management (Hill, 1991a; Feachem *et al*., 1992; Vallin, 1992). Such actions culminated in the introduction and establishment of the primary health care strategy in most countries in the late 1970s and early 1980s.

Significant variations in disease types and patterns are known to exist between the different parts of the continent due to physical features and other factors associated with the environment. Researchers have noted the high incidence of malaria and other infectious diseases in West Africa compared with other parts of the continent, due mainly to low altitude and absence of slopes to ease drainage (see Cantrelle, 1972; Blacker, 1991). Furthermore, population densities, especially within the residential set-up, are also higher in West Africa. Together with the region’s clustered settlement patterns, the environment is conducive to faster transmission of infectious diseases than in many other parts of Sub-Saharan Africa (Root, 1999). As a result, at least until recently survival conditions appear to have been more adverse in Western Africa than other parts of the continent.

Despite the initiatives taken in the second half of the twentieth century and the call for "health for all by 2000" by the World Health Organization (WHO) and almost all African governments, Sub-Saharan Africa enters the twenty-first century as the highest mortality region in the world with children accounting for the greater proportion of deaths. The severest peacetime childhood mortality ever recorded in the contemporary world has been found in African countries — Sierra Leone, Malawi, Mali and The Gambia being examples worth noting (Hill, 1991a). In fact, the gap between Africa and other continents has increased over the past two decades as a result of the economic difficulties that afflicted most African countries since the 1970s (Vallin, 1992; see also Jolly and Cornia, 1984; Cornia *et al*., 1988; and National Research Council, 1993).

## 2.5 Attempts of Establishing Prevailing Patterns of Childhood Mortality

One of the main aims of assessing age patterns of childhood mortality is to identify the age-specific causes of death (Bicego and Ahmad, 1996). Knowledge of the distribution of mortality risk across age groups is of relevance in the design of health and other social and economic programmes aimed at mortality reduction. In fact, Woods *et al*. (1997) opined that

> "mortality in infancy and early childhood need to be differentiated in all populations with low life expectancy. Many important issues for health policy formulation and several important questions that have a major bearing on our understanding of past and present demographies will be ignored if this simple guide is not adopted".

The distribution of under-5 deaths between the age groups 0-1 and 1-5 can vary substantially. Although the causes of such variations have not been established conclusively, it is contended that populations in close geographic proximity tend to manifest similar age patterns of mortality in childhood thus suggesting that culture and the environment can be contributory factors (Bicego and Ahmad, 1996). Hill (1995), however, observed that the ratio of infant to child mortality increases as overall mortality falls; and within infancy, the ratio of neonatal to post-neonatal mortality similarly increases as overall mortality falls. He described this as the reflection of the declining relative importance of communicable diseases and the increasing relative importance of non-communicable conditions such as congenital disorders as overall mortality falls.

Cantrelle and Leridon (1971) were among the first to study in detail the mortality patterns in childhood in Sub-Saharan Africa. Using reliable multi-round data collected between 1962 and 1965 from a small area in rural Senegal, they observed a high infant mortality rate comparable to rates for Europe in about the eighteenth century. They were surprised, however, to note that the mortality rate for the second year of life was of the same magnitude as the first. Upon examining the mortality curve between birth and age five, it was observed that, while the first three months were quite normal compared with other known populations, there was a spectacular rise between the fifth and tenth months and a rather gradual fall becoming apparent only at about age 12 months. They concluded that this was quite unusual and unlike any existing type of life table.

Following this unexpected observation, Cantrelle (1972) further considered the possibility of the existence of a distinctive pattern of tropical mortality. He postulated that since model life tables such as the Princeton families were based on different mortality patterns which approximate to geographical groupings, it was likely that other different mortality patterns would emerge as more data became available. Although constrained by lack of data for other regions in the continent, he was able to show similarities between the rural Senegalese communities that he studied in detail with a village in The Gambia, a community in Burkina Faso, and another in Guatemala outside the continent. The existence a rise in mortality between the ages 5 and 10 months was also confirmed in Indian Punjab (Cantrelle, 1972). In an attempt to explain the reason for such a difference from historical non-tropical populations, Cantrelle (1972) speculated from two perspectives, viz.: differences in disease and cause-of-death structures of the contemporary African communities compared with those in eighteenth century Europe; and differences in the constituents of the environment, especially climate and topography.

Subsequent similar longitudinal studies in a different rural setting in Senegal, Bandafassi, confirmed the existence of this peculiar pattern of child mortality (Pison and Langaney, 1985). In neighbouring Mali, Hill *et al.* (1983) diversified their approach to studying childhood mortality patterns by bringing in the element of ethnicity and the immediate environment. Of the four rural populations they focused on, only one manifested a childhood mortality pattern similar to that reported earlier in rural Senegal. The other three populations depicted a completely different pattern. Blacker *et al*. (1985), changed the approach by introducing national populations into the analysis using World Fertility Survey data. They confirmed the prevalence of the unusually high post-infant mortality levels in many West African countries, but found that it was not characteristic of the bulk of the rest of the continent. More importantly, they arrived at the following conclusions that probably raise more questions than they answer about the characteristics of Sub-Saharan African mortality:

- both within childhood and overall, age patterns of mortality in Sub-Saharan Africa vary greatly;

- populations with similar levels of mortality and populations in close geographical proximity can exhibit very different mortality patterns contrary to earlier beliefs; and perhaps most important of all

- none of the one-parameter families of model life tables provide a satisfactory description of the age patterns of mortality identified.

This third conclusion, of course, has significant implications for the indirect mortality estimation techniques that the majority of Sub-Saharan African countries still use to derive recent levels and trends in childhood mortality. It is in the study of mortality trends that indirect estimates are most sensitive to the age pattern of mortality (Blacker *et al*., 1985).

A more recent attempt to shed light on what had become an interesting but complex piece of African demography is the exposition given a decade later by Hill (1995), albeit as part of a much larger study in terms of geographical coverage. In his attempt to search for similarities of child mortality patterns in different regions of the developing world using WFS and DHS birth histories, comparing observed patterns with those depicted in the Princeton Model Life Tables, Hill detected high post-infant child mortality relative to infant mortality in sub-Saharan Africa. Specifically, he noted the following for the three main regions in sub-Saharan Africa:

*i. East Africa:*

- In Kenya and Zimbabwe, the pattern of child mortality closely approximates the Princeton "North" models. This, to an extent, corroborates Ewbank's (1990) earlier assertion that the age pattern of mortality between ages 1 and 20 in East

Africa is best described by the North model life tables with a value of β of about 0.95 in Brass' relational logit system.

- In Burundi, Malawi and Rwanda, child mortality relative to infant mortality is observed to be even higher than would be expected on the basis of the "North" family.

*ii. Southern Africa:*

- Estimates of child mortality from the Botswana DHS indicate an age pattern of child mortality that falls perfectly on the "North" pattern; whereas those obtained from Lesotho (from the WFS) fall close to the "East" pattern. Despite the use of just two data sets, Hill contended that it appears possible that there are marked differences in age patterns of child mortality in Southern Africa, thus confirming one of the main conclusions of Blacker *et al*. (1985).

*iii. Western and Central Africa:*

- Senegal and Mali DHS and Senegal WFS data show extreme patterns of high child mortality relative to infant mortality, with child mortality well above the expected levels in either the "North" or "South" families given the observed levels of infant mortality.

- Along the Gulf of Guinea, Ghana, Benin, Nigeria and Cameroon manifest patterns that track the "North" family closely, but with a slightly higher level of child mortality. A multi-round survey in Côte d'Ivoire suggested a similar "North" pattern, although estimates derived from the WFS indicated more of a "West" pattern.

- For Liberia, both DHS and multi-round survey data clearly revealed a "West" family pattern of child mortality.

In a similar assessment using a wider range of DHS data, Bicego and Ahmad (1996) observed two phenomena related to age patterns of mortality in childhood, viz.: shifts in age pattern of mortality during mortality decline; and unusually high ${}_4q_1/{}_5q_0$ ratios relative to the Princeton Model Life Tables. Again, they singled out the Sahel region as being characterised by extremely high child mortality relative to infant mortality as noted by Blacker *et al*. (1985) and Hill (1995).

Despite revealing large variations in age patterns of childhood mortality within Sub-Saharan Africa, all these aforementioned studies fall short of giving a clear picture as to the extent to which such variations in mortality patterns prevail in the continent. None attempted a cartographic representation of the geographical distribution of the existing childhood mortality patterns for the countries for which information is available. These were perhaps the issues Root (1999) had in mind in his recent attempt to put childhood mortality patterns in Sub-Saharan Africa clearly into context. His study was the first that considered investigating sub-national mortality levels for spatially contiguous countries in Sub-Saharan Africa. However, he mapped the levels of ${}_5q_0$ observed instead of the relationships between ${}_1q_0$ and ${}_4q_1$; and his investigation of the rather complex relationships between ${}_1q_0$ and ${}_4q_1$ was based on a simple linear regression of ${}_4q_1$ on ${}_1q_0$ for West African countries on the one hand, and East and Southern African countries on the other. The resulting low $r^2$ values from his simple models are an attestation to the complexity of the relationship. In fact, all existing model life tables systems have shown such a relationship to have an element of curvature at ${}_5q_0$ levels of less than 200 per 1,000. As a result, Root (1999) only succeeded in confirming the fact that taken together, West African countries and their sub-regions tend to have unusually higher levels of child mortality relative to infant mortality than Eastern and Southern African countries. Notwithstanding this, there are quite a number of national sub-regions in West Africa with ${}_1q_0$ and ${}_4q_1$ distributions similar to those that prevail in Eastern and Southern Africa.

It is worthwhile to focus on the peculiar pattern of high child mortality relative to infant mortality consistently reported to prevail in West Africa especially the Sahel region. In the entire developed world and most parts of the developing world, the level of child mortality is lower that that of infant mortality (Hill, 1995; Bicego and Ahmad, 1996), and has eventually become a universally accepted demographic convention. However, Woods *et al*. (1997) challenge this view having shown that the situation observed in West Africa prevailed, albeit briefly, in England and Wales in the nineteenth century. Therefore, the pattern may be unique to West African populations in the contemporary world, but has prevailed in other parts of the world in the past. It may be contended that it is a temporary outcome of mortality transition, but proof of that will not be attempted in this study. With reference to West Africa, Woods *et* *al*. (1997) postulate that children in the age group 2-4 years are especially vulnerable to the ravages of malaria and measles and that, since the average age at weaning is about 24 months, deaths from diarrhoea-related diseases are expected to be especially prominent in the third year of life. They conclude that in such circumstances, the practice of prolonged breastfeeding and the particular disease environment make it likely, not only that early-age mortality will be especially high, but also that many deaths will be postponed from infancy to later years.

## 2.6 The Threat Posed by the AIDS Epidemic

### *2.6.1 Implications for Childhood Mortality Levels*

AIDS is undoubtedly having a tremendous impact on almost every aspect of life in sub-Saharan Africa. However, because of the region's poor status in terms of adequate and reliable demographic and epidemiological data, much of what was known on the issue until recently (as shown in the available literature) relied heavily on models and estimates (Awusabo-Asare *et al*., 1997). Whilst the complexities surrounding the demographic impact of the AIDS epidemic on populations are still being documented, this section focuses on its direct effect on childhood mortality. In assessing the impact of the AIDS epidemic in Sub-Saharan Africa using national Demographic and Health Surveys, Timaeus (1998) observed that under-5 mortality is stagnant or rising in several African countries. In some countries, however, he noted that adverse trends developed too early in the 1980s to be attributable to HIV. In a similar investigation including other parts of the developing world and still using data from national Demographic and Health Surveys, Adetunji (2000) produced results suggesting that the direct effects of adult HIV/AID may not be as large as they have generally been thought to be.

On the contrary, findings from many recent community studies in Sub-Saharan Africa aimed at shedding more light — in demographic terms — on the gravity and potential threats of the HIV epidemic in the continent have yielded a more adverse picture. Some of such studies indicate a two to three-fold increase in total adult mortality, with an even larger increase in mortality among young adults in communities with adult HIV prevalence levels under 10 per cent (Boerma *et al*., 1998). In Kisesa, Tanzania, for instance, Boerma *et al*. (1997) observed an increase in adult mortality by one-third as a result of HIV/AIDS, and predicted further increase.

With respect to children, Foster (1998) asserts that AIDS has started reversing recent declines achieved in infant and child mortality rates around the world, with the southern African countries currently experiencing severe HIV epidemics being the worst affected areas. Ntozi and Nakanaabi, (1997) observed a similar pattern in six eastern, southern and western districts in Uganda within a year after the first AIDS case was reported in the country. Based on current trends, for instance, child mortality is projected to increase fourfold in Zimbabwe by 2010, threefold in Botswana, and by a factor of two in Kenya and Zambia (Foster, 1998). Comparing results from various maternity-based studies from Southern, Eastern and Western Africa, Boerma *et al*. (1998) show that infant and early child mortality among children of HIV-infected mothers is 2 to 5 times higher than among children of HIV-negative mothers. Two-thirds of AIDS deaths among children occur at ages 1-4 years (Foster, 1997).

Adult deaths from AIDS undoubtedly increase the number of orphans (Ntozi, 1997; Foster, 1997). These orphans have to be cared for mainly within the extended family system. The care they receive may be of poor quality due to reduced family resources or the absence of maternal/paternal-filial attachment. As noted by Ntozi and Nakanaabi (1997) in the case of Uganda, orphans with one surviving parent do better — probably meaning a better quality of life — than those under the care of other guardians. One would therefore expect orphans without any surviving parent to have poorer nutritional status, poorer health care and attention, thus exposing them to greater risks of death at early stages in life — especially if they are under five years of age.

Models have indicated that, although as much as 80% of children infected with HIV will die by age 5, AIDS is probably responsible for only about 3% of all deaths to infants and children in Africa (Ewbank and Gribble, 1993; Timaeus, 1998). Adding to this the extra child deaths resulting from orphanhood among HIV-negative children born to HIV-positive mothers would increase this percentage only slightly (Ewbank and Gribble, 1993).

### *2.6.2 Possible Methodological Implications*

In addition to the threat that AIDS poses to the demographic future of sub-Saharan Africa, the epidemic has created methodological problems for the technical demographer. It is to breach the assumptions made by many direct and indirect methods of measuring or estimating demographic indicators. No adequate way has been found as yet to correct AIDS-related biases in the indirect technique of estimating childhood mortality. Notwithstanding this, Brass (1996) opined that the increase in the number of deaths from AIDS has affected the structure of mortality, thus raising new issues in mortality measurement. He also noted the possibility that deaths from AIDS will alter the age pattern of mortality to such an extent that general results from quasi-stable population theory would require modification.

As far as ${}_5q_0$ estimation is concerned, reports by mothers on the deaths of their children may be distorted by the selection of respondents for survival. But based on information available at the time of writing, Brass (1996) concluded that the distortion caused by AIDS will not destroy the effectiveness of indirect techniques. However, modifications may prove to be necessary to retain accuracy.

# Chapter 3

# Model Life Table Systems and their Application in the Search for Childhood Mortality Patterns[3]

## 3.1 Introduction

The bulk of the data used in the construction of the most widely used model life table systems derive from pre-industrial European populations (Coale *et al.*, 1983) or developing country populations outside Sub-Saharan Africa (United Nations, 1982a). Therefore, it is justified to question whether such model systems show characteristics similar to mortality in Sub-Saharan Africa, and to childhood mortality in particular. Specifically, to what extent does the impact on the age pattern of mortality of mortality decline characteristic of each of the model systems reflect the situation in Sub-Saharan Africa? In the event that a model system fails to adequately describe the general age pattern of mortality in Sub-Saharan African populations, does that necessarily imply inadequacy of the system in describing the age pattern of mortality in childhood for the same populations? And finally, among the existing model life table systems, which presents the greatest potential in the identification and classification of prevailing distinct mortality patterns in childhood in the continent?

Essentially, these questions relate to the appropriateness and applicability of existing model life table systems for the study of childhood mortality in Sub-Saharan Africa, and warrant an evaluation of their suitability in the context of Sub-Saharan African mortality studies with a view to adopting one system in the subsequent analysis of childhood mortality patterns in the continent. The selection process will adopt a two-stage comparison of model systems. The first stage attempts to establish whether, at given levels of general or all-age mortality, the model systems show ${}_5q_0$ levels that are uncommon in the continent — in the past or currently. The second stage focuses on the range of distinct and identifiable childhood mortality patterns in terms of the relationship between infant (${}_1q_0$) and child (${}_4q_1$) mortality.

This chapter, therefore, provides a review of the model systems that highlights their underlying concepts, evolution and modes of construction, as well as major criticisms levelled against each of them. It presents a systematic comparison of existing model life table systems, the aim of which is to identify the most appropriate for the investigation of childhood mortality patterns in Sub-Saharan Africa.

## 3.2 Review of Model Life Table Systems

Attempts to establish the relationship between mortality and age originate with the pioneering work of John Graunt in the seventeenth century. Such approaches to the description of the age pattern of human mortality can be categorised into three groups of techniques, analytical or mathematical representations; empirical or tabular representations; and relational models. While analytical models are considered in this section in as much as they relate to childhood mortality, the greater part of this review is focused on empirical models. The relational model, which combines features of the tabular model life table approach and the mathematical approach, is a useful tool in the statistical modelling of childhood mortality patterns in Sub-Saharan Africa. It is considered and reviewed in detail in chapter 7.

The first mathematical expression of mortality risk as a function of age was proposed by Gompertz in 1825 as:

$$\mu(x) = \alpha \cdot e^{\beta x}$$

where $\mu(x)$ is the force of mortality, and $\alpha$ and $\beta$ are parameters representing the level and pattern of mortality in the population respectively. However, this expression was supposed to represent only “underlying” mortality, i.e. mortality purged of accidental or infectious causes (Preston *et al*. 2001). As a means of accommodating these two important causes of death — which are assumed to act independently of age — Makeham modified Gompertz’s expression in 1860 by simply adding a constant to yield

$$\mu(x) = \alpha \cdot e^{\beta x} + \gamma.$$

Although both expressions are still used to smooth mortality data especially at older ages, their ability to describe mortality at the younger ages of populations is limited. For instance, Vaupel *et al*. (1979) and Horiuchi and Coale (1990) have shown that both formulae tend to over predict mortality at these young ages, including childhood.

In a recent attempt to develop an analytical model, Heligman and Pollard (1980) propose an eight-parameter equation for mortality at all ages. It expresses the conditional probability of dying between age $x$ and $x$+1, $q(x)$, as:

$$\frac{q(x)}{1-q(x)} = A^{(x+B)^C} + De^{-E(\ln(x)-\ln(F))^2} + GH^x$$

The three components of the right hand side of the equation relate to mortality in childhood, young adulthood, and elderly respectively. The parameters of the first term, i.e. $A$, $B$ and $C$, represent the level of mortality, an age displacement to account for infant mortality, and the rate of mortality decline in childhood respectively. High values of the coefficient $C$ necessarily imply rapid declines of mortality within childhood. As indicated in the previous chapter, Cantrelle and Leridon (1971) and Hill *et al*. (1983) have demonstrated that in some Sub-Saharan African populations, mortality declines in childhood are reversed at age three or six months. This is impossible in Heligman and Pollard's formulation. This shortcoming, and the large number of parameters that the model has, render it rather unsuitable for use in attempts to describe national and sub-national mortality patterns in Sub-Saharan Africa.

Model life tables were developed to deal with situations of missing, inadequate, or inaccurate data — which is the usual situation in Sub-Saharan Africa. Several sets of empirical model life table systems have been developed since the middle of the last century. This can be attributed to two main reasons. Lack of reliable data continues to constrain methodological advances in the measurement of demographic processes and indicators; and secondly, human processes are too complex to be represented by simple models that are applicable in all regions of the world. However, the successive model life table systems reflect methodological improvements from one set to the other, that result from the efforts demographers have put into the subject. Some eight sets of empirical model life tables exist and some were introduced as recently as in the last decade. These are the United Nations Models (United Nations, 1955; 1956); the Princeton or Regional or Coale-Demeny Models (Coale and Demeny, 1966; Coale *et al.*, 1983); the Ledermann Models (Ledermann, 1969); the New United Nations Models (United Nations, 1982b); the West African Hypothetical Model (United Nations, 1982a); the

Models of the Organisation of Economic Co-operation and Development (OECD) proposed in 1982; Revised Regional Models at Very Low Levels of Mortality (Coale and Guo, 1989); and the New Models for High-Mortality Populations (Preston *et al*., 1993).

As this thesis focuses on Sub-Saharan Africa, it is unnecessary to review the revised model life tables for low mortality populations proposed by Coale and Guo (1989). In addition, the Ledermann and OECD models are excluded from the following review because of their inability to offer much to Sub-Saharan African mortality studies. Specifically, the Ledermann models are generally criticised for being based on flawed data, with some of the empirical base tables having been smoothed before use (Preston *et al*., 2001).

Although developed from empirical life tables obtained from developing countries, the OECD models, on the other hand, do not provide survivorship in single years for the childhood ages which renders them unsuitable for use in the investigation of mortality patterns within childhood. The review therefore focuses on the first United Nations models, the Princeton or Coale-Demeny models, the New United Nations models, the West African Hypothetical model, and the New Models for High-Mortality Populations.

### *3.2.1 United Nations Model Life Tables*

Despite being based on the same data as the Ledermann models mentioned above, the United Nations model life tables deserve mention because they are the first such models to be developed; and their relative simplicity makes them useful as an introduction to other model life table systems (Newell, 1988). Nevertheless, they are very rarely used now. They are based on 158 empirical life tables for each sex selected from tables published in the first half of the twentieth century (Coale and Demeny, 1966), and were not subjected to a rigorous data quality check (Preston *et al*., 2001). Using a regression technique that assumes interdependence of adjacent age-specific mortality rates — thus forming a chaining process starting from ${}_1q_0$ and thereby accumulating biases — the construction produced twenty-four model life tables for each sex. In steps of 5, they run from level 0 with a life expectancy at birth ($e_0$) of 20 years to level 115 with a corresponding $e_0$ of about 75 years.

As expected of new developments in any discipline, this model system generated an intense debate and criticisms, especially for the statistical bias introduced in their construction (see Gabriel and Ronen, 1958). Other criticisms levelled against the system are that:

i. the models that relate to high mortality are based on a small number of life tables which were also the least reliable among the base empirical tables; and

ii. the models are inflexible and rigid because of their one-parameter nature. Each level of mortality corresponds to a unique model life table.

Notwithstanding, the system dominated the field of mortality research for the ensuing decade until Coale and Demeny produced the Princeton Regional Model Life Tables in 1966.

### *3.2.2 Princeton Regional Model Life Table System*

With a view to correcting some of the criticisms levelled against the United Nations Model life tables, Coale and Demeny (1966) used a set of 326 carefully evaluated life tables (unaffected by war or epidemics) for each sex in the construction of the Princeton Regional model life tables. Developed in 1966 and revised in 1983, this remains the most widely used model life table system in contemporary demographic research. The life tables comprise twenty-five Levels for each sex (twenty-four in the original set) and are called Levels 1 to 25 (unlike the United Nations tables, which are labelled in steps of 5). They correspond to life expectancies at birth ranging from 20 to 80 years for females, and from just over 17 years to a little over 77 years for males. One difference of this system from that of the United Nations is that it is built around four 'families' of 'regions' called "North", "South", "East" and "West", with a set of models for each family depicting different age patterns of mortality.

The majority of the empirical tables used in the construction of the model system were drawn from Europe. The lowest observed life expectancies at birth are 33.4 years for males (Bavaria, 1878) and 35.5 years for females (Italy, 1876-87). The 326 base tables were divided into nine groups according to the patterns of mortality they manifested. Five such groups were eventually discarded for reasons ranging from the number or inaccuracy of the bulk of the base tables to observed patterns strongly influenced by tuberculosis mortality. The remaining four groups form the basis of the Princeton Regional model life table system.

Using ordinary least squares, the model life tables were generated with probabilities of dying between exact ages *x* and *x+n* derived from the relationship

$$ {}_{n}q_{x} = a_{x} + b_{x} \cdot e_{10} $$

for situations of high mortality; and

$$ \log(100{,}000 \cdot {}_{n}q_{x}) = a_{x}^{*} + b_{x}^{*} \cdot e_{10} $$

in cases of low mortality. The expectation of life at age 10, $e_{10}$, considered to be a reliable indicator of general mortality and largely unaffected by the mortality rates of any age group, was used as the independent variable in both situations.

The “North” family is characterised by low infant and old age mortality, but high adult mortality. The “South” pattern manifests high under-five mortality, especially in infancy, low adult mortality and high mortality at ages over 65 years. The “East” family also has high infant and high old-age mortality relative to child and adult rates; and the “West” family displays a pattern described as the average of the other three families. It is the pattern often recommended in instances where there is no reliable information on the age pattern of mortality.

One main reason why this model system became commonly used is probably that each life table has an associated stable population model with various demographic parameters ranging from crude birth and death rates to total fertility rates, for rates of growth spanning –1 to 5 per cent per annum in steps of 0.5. These features facilitate the estimation of demographic indicators for populations or countries with defective vital registration systems, but with at least one reliable age distribution. Also, many indirect estimation procedures — especially the estimation of under-five mortality using Brass’s technique (Brass, 1964; Brass and Coale,

1968) — evolved methodologically around the Princeton Regional models, with sets of estimation coefficients or multiplying factors available for each "family" (see Trussell, 1975).

The main criticism levelled against the Princeton Regional Model Life Table is that it reflects the mortality experience of European populations, and may not be appropriate for studying mortality in developing countries — especially Sub-Saharan Africa. None of the empirical tables used in its construction incorporated mortality from malaria as high as is found in contemporary Africa (Preston *et al*., 2001). Also, Coale *et al*. (1983) had to extrapolate from their data to construct model life tables for high mortality situations with life expectancies as low as 20 years. The same applies to the very low mortality life tables.

### *3.2.3 New United Nations Model Life Table System*

Although the United Nations came up with a set of model life tables for developing countries in 1982 based on mortality experiences of populations from the developing world — including the tropical regions — their construction is also characterised by the absence of data from Sub-Saharan Africa (United Nations, 1982a; 1982b). A total of 72 empirical life tables (36 for each sex) was obtained from the developing world with lowest life expectancies at birth of 37.6 years for males and 40.1 years for females. Principal components analysis was adopted to group the empirical tables into clusters with common mortality patterns.

The procedure identified four age patterns of mortality labelled the "Latin American" pattern, the "Chilean" pattern, the "South Asian" pattern, and the "Far Eastern" pattern according to the geographical region which is predominant within each group. A fifth pattern, called the "General" pattern was also generated from all the empirical life tables combined, including those not contained in any of the four regional patterns.

Compared with the Princeton "West" Regional pattern, the "Latin American" pattern has relatively high infant and child mortality, high adult mortality and relatively low old-age mortality. The "Chilean" model also demonstrates extremely high infant mortality; whilst the "South Asian" shows high mortality under age 15 and over age 55 years, but relatively low level of adult mortality. The peculiarity of the "Far Eastern" pattern is its high old-age mortality, while the "General" model is similar to the Princeton "West" Regional pattern. However, none of the models exhibit the very low levels of infant relative to child mortality that are depicted by the Princeton "North" family of model life tables, and are thought to be common in Sub-Saharan Africa.

Like the Princeton Regional system, the New United Nations model system of life tables is a double-entry system. Life tables are tabulated for each sex for expectations of life at birth ranging from 35 to 75 years in single-year interval. They are accompanied by stable population models with various demographic parameters similar to those of the Princeton system.

### *3.2.4 Hypothetical West African Model*

As it had become quite apparent since the work of Cantrelle and Leridon (1971) that unusual patterns of mortality exist in some West African populations especially in childhood, the United Nations (1982a) published the Hypothetical West African model life table believed to be applicable to these specific populations. The only source of data was a set of observed ${}_nq_x$ values obtained from a population laboratory at Ngayokheme, a small rural area in Senegal.

Because all those concerned were born after the institution of the surveillance system, the data pertaining to ages below 10 years were regarded as free from under-reporting or age mis-statement errors. At ages 10 and over, age mis-statement was very much apparent, necessitating the smoothing of observed ${}_nq_x$ values before establishing the prevailing pattern of mortality. A three-component adjustment to the New United Nations "General" pattern fitted the resulting ${}_nq_x$s well.

On the basis of the hypothesis that the essential features of the Ngayokheme pattern might be representative of the whole of West Africa, the smoothed ${}_nq_x$s formed the basis for the construction of the Hypothetical West African Model using the same procedure as in the construction of the New United Nations Models (United Nations, 1982a). This resulted in two sets of model life tables — one for males and another for females — for life expectancies at birth from 25 years to 55 years at five-year intervals.

The obvious limitation of this model is its underlying hypothesis. Hill *et al*. (1983) have shown that different sub-national populations display different mortality patterns in childhood in Sahel West Africa and the extent to which the features of the Ngayokheme pattern are common in West Africa, especially in coastal countries, has not been established.

### *3.2.5 New Model Life Tables for High-Mortality Populations*

Preston *et al*. (1993) develop a set of New Model Life Tables for use in studies relating to high-mortality populations in the past. The construction of these tables was inspired by the fact that tables of the Princeton system with life expectancies between 20 and 32 years are based on extrapolations beyond the empirical tables on which they are based.

The data on which the New Model Life Tables are based pertain to the population of African-Americans who moved to Liberia between 1820 and 1843 (Preston *et al*., 1993). The authors argue that these data provide a previously unavailable baseline to which high-mortality models can be anchored. The unusual intensity of mortality in this population can be attributed to an enormous burden of infectious disease to which the migrants had no immunity upon arrival, a fact clearly acknowledged by the authors.

The New Model Life Tables were constructed by combining the UN General Standard model life table system with the Liberian data using the relationship

$$\text{logit}\, l_x^i = \alpha_i + \beta_i \,\text{logit}\, l_x^s$$

where $l_x^s$ is the probability of survival to age *x*, used as a "standard" life table representative of a model life table system;

$l_x^i$ is the probability of survival to age *x* in life table *i* belonging to that model life table system;

$\alpha_i$ and $\beta_i$ are parameters representing the level and pattern of mortality.

(Logit is a mathematical transformation defined as logit $x = \log_e[x/(1-x)]$).

Essentially, for each sex, the life table in the New United Nations "General" model life table with life expectancy at birth of 35 years is adopted as a standard and regression used to estimate the parameters, $\alpha$ and $\beta$, that most efficiently map the Liberian data onto that life table. This is the underlying principle of the relational life table model discussed in more detail in chapter 7. It implies that any life table within a model life table system can be efficiently represented as a two-parameter linear transformation of a standard life table for that system.

Having identified the sets of $\alpha$ and $\beta$ that transform the UN General model with $e_0$ of 35 years to itself on one end (i.e. 0 and 1 respectively) and to the Liberian data for males and females at the other end (say $\alpha_m$ and $\beta_m$ for males, $\alpha_f$ and $\beta_f$ for females), corresponding values of $\alpha$ and $\beta$ are computed by iteration to depict life expectancies at birth ranging from 2 years to 32 years in two-year intervals. The outcome, therefore, is a single-entry model system with a set of sixteen model life tables for each sex.

## 3.3 Applicability of Model Systems in the Case of Sub-Saharan Africa

The tropics, in which sub-Saharan Africa falls, are characterised by a range of infectious diseases and deficiency diseases specific to that kind of environment, e.g. malaria. Other diseases that are known to be almost universal, such as measles, can cause much higher mortality in the tropical regions than they did in pre-industrial Europe (Cantrelle, 1972). Infectious disease and malnutrition are intermediate factors in childhood mortality that are dependent on variables in the physical environment (see Mosley and Chen, 1984). As a result, the tropical environment poses problems to human survival which are perhaps more difficult to overcome than is the case in other environments. Such an effect is bound to reflect itself in the mortality schedules of populations living in such environments. Another factor worth consideration is the wide range of unique traditional/cultural beliefs and practices that vary from one population to another. These influence the way of life and living conditions of populations in different ways with the potential to have significant effects on survival chances at various ages. Since the United Nations (1982a) has contended that the age pattern of mortality in a population encapsulates that population's history of death and disease during the previous three or four generations — i.e. it is a reflection of past levels, cohort age patterns, and trends of illness and consequent recovery or death — it will not be surprising if existing Model Life Tables do not reflect the mortality situations in the continent.

After several attempts to estimate childhood mortality indirectly using the Princeton model families as standard, Brass and Coale (1968) opined that *"the standard life table to be used in [Sub-Saharan] Africa ... should ideally incorporate typical features (if such exist) of [Sub-Saharan] African age patterns of mortality"*. It is against this background that Brass proposed the "African standard" mortality schedule which reflects features that appeared to be common in Sub-Saharan Africa. The survival ($l_x$) curve of this model is such that up to age 10 or 20, it is similar to that of a Princeton "North" model with $e_0$ of about 46 years; but after age 20 the survival curve falls much more sharply than a "North" model life table with the same level of child mortality, and faster than the "South", "East", or "West" with the same level of child mortality (Brass and Coale, 1968).

## 3.4 Analytical Comparison of Existing Model Life Table Systems

In attempting to use any model system of life tables in the investigation of childhood mortality, one should consider the following questions:

i. To what extent does the model system fit or reflect the relationship between childhood mortality and overall mortality for the population or populations concerned?

ii. Focusing on childhood mortality only, does the model system offer a wide range of patterns in terms of the relationship between infant (${}_1q_0$) and child (${}_4q_1$) mortality?

An attempt is made below at the comparison of the four aforementioned model life table systems along the lines of these questions.

### 3.4.1 *Life Expectancies at Birth and Implied Under-5 Mortality Levels*

One way of assessing the appropriateness and applicability of model life table systems for the study of childhood mortality in Sub-Saharan Africa is to examine their depicted levels of $_5q_0$ against corresponding life expectancies at birth, and compare the resulting distribution with the situation in the continent. Figure 3.1 shows a graphical representation of declining levels of $_5q_0$ with improving mortality conditions in each of the four model systems considered. Not only does the graph give indications of the inherent rates of decline of $_5q_0$ with increasing levels of life expectancy ($e_0$), it also gives a fair comparison of the intensity of mortality at age five and over as one would expect in populations manifesting similar characteristics as these models. It should be noted, though, that populations affected by HIV/AIDS may develop different relationships between $_5q_0$ and $e_0$ from what the model systems show.

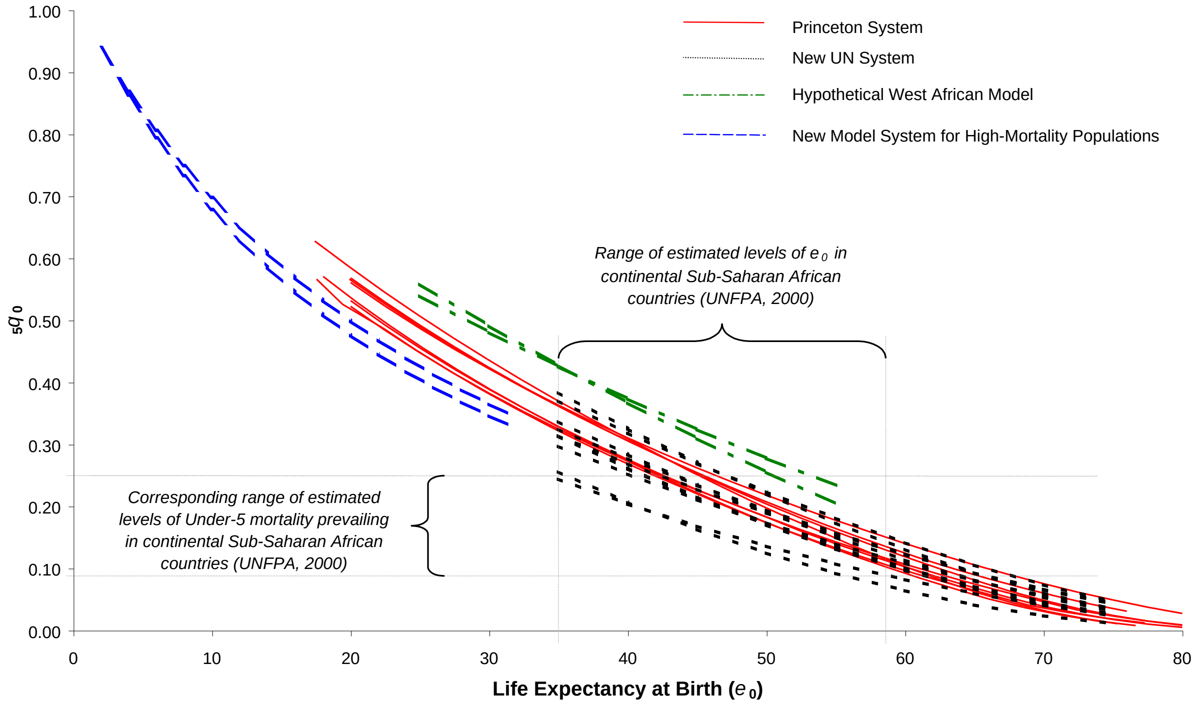



**Figure 3.1:** ***Levels of $_5q_0$ implied by model life table systems at various levels of life expectancy at birth.***
***Sources: United Nations (1982b); Coale et al. (1983); Preston et al. (1993)***

Overall, none of the four model systems show any unusual or irregular relationship between ${}_5q_0$ and $e_0$. In all cases, the decline in ${}_5q_0$ with increasing $e_0$ follows an exponentially reducing trend, tapering off with extremely low under-5 mortality levels at life expectancies at birth between 75 and 80 years. However, each system has its own specificities, as one would expect. Considering the Princeton system first, the four families differ by a rather narrow and constant range of ${}_5q_0$ across the entire span of life expectancies at birth they cover. At high levels of mortality, this range of implied ${}_5q_0$ levels is bordered at the upper end by the "East" model family, and at the lower end by the "North" family. And at lower levels of mortality, the "West" family has the lowest levels of ${}_5q_0$ but only differs slightly from the "North" and "East" families, while the "South" family displays the highest under-5 mortality, thus forming the upper end of the range depicted by the Princeton system. This therefore implies that the "East" family changes within this rather narrow range from having the highest implied ${}_5q_0$ levels at high mortality to close to the lowest implied ${}_5q_0$ at overall low mortality.

The New United Nations system displays a slightly wider range of corresponding levels of ${}_5q_0$ for different families for any given $e_0$ at birth. Unlike the Princeton system, the New United Nations system families converge as mortality improves. The range is bordered at the upper end by the "South Asian" model family and at the lower end by the "Far Eastern" family. However, if the "Far Eastern" family is excluded, the remaining four model families of the New United Nations system trace out a range of ${}_5q_0$ levels very similar to those of the Princeton system. It is only at life expectancies at birth of between 35 and 45 that the New United Nations range of ${}_5q_0$ is wider than that of the Princeton system.

The Hypothetical West African model, developed for and based on data from a region with exceptionally high level of childhood mortality, indeed has much higher corresponding levels of ${}_5q_0$ for life expectancies at birth ranging from 25 to 55 years than either the Princeton or New United Nations systems. It has much higher under-5 mortality than the New Model for High-Mortality Populations for overlapping life expectancies at birth, i.e. 25 to 32 years.

As noted earlier, one of the main reasons that led to the construction of the New Model for High-Mortality Populations was the fact that Princeton models with life expectancies at birth of less than 33 years extrapolate beyond the levels of mortality in the observed life tables on which they are based. One needs to be cautious in the application and interpretation of these extrapolated model life tables. As can be seen from Figure 3.1, the model proposed by Preston *et al*. (1993) yields lower levels of ${}_5q_0$ than any of the Princeton model families for life expectancies at birth ranging from 17 to 32 years. As the description of its mode of construction in the previous section would suggest, the New Model from Preston *et al*. appears very much like an extension of the "General" model family of the New United Nations system, notwithsatnding the gap of three years in life expectancy separating the best mortality conditions in the New Model for High-Mortality Populations and the worst mortality conditions in the "General" model Pattern.

The depicted distribution of the relationships between ${}_5q_0$ and overall mortality in terms of life expectancy at birth from another perspective gives an indication of mortality at age 5 years and over for each of these model systems. It can be inferred from Figure 3.1 that the Hypothetical West African model implies lighter mortality from age 5 and over than any of the other model systems for mortality levels with life expectancy at birth ranging from 25 to 55 years. The "Far Eastern" family of the New United Nations system, which is characterised by high mortality at the old ages ascribable to a past history of tuberculosis in the regions from which its empirical tables were derived (Newell, 1988), depicts the worst mortality situation from age 5 years and over in the life tables with life expectancy at birth ranging from 35 to 75 years.

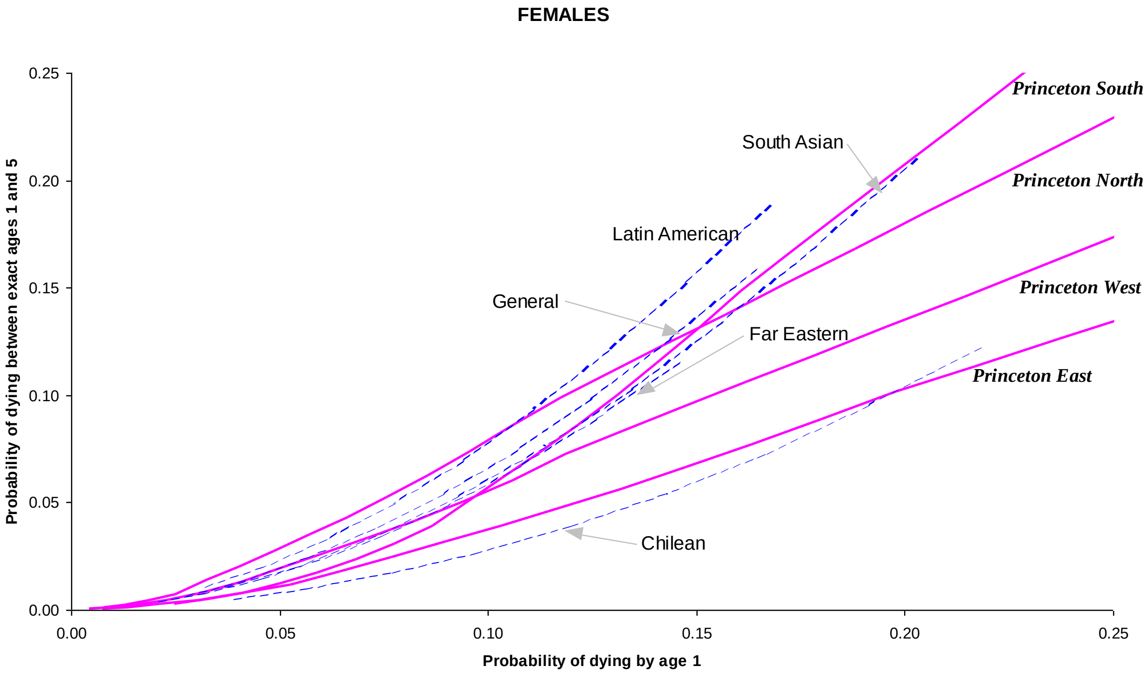
Overall, the characteristics of mortality depicted by the relationship between under-5 and overall mortality in the model life table systems considered do not readily show any peculiarities that renders them markedly different from what prevails in national populations in Sub-Saharan Africa despite the limitations of the available literature. Notwithstanding the extremely low range of life expectancy at birth covered the New Model for High-Mortality Populations, it may be premature to exclude it in the subsequent stage of the assessment of model life table systems because it may suit contemporary sub-national populations in Sub-Saharan Africa with unusually low life expectancies at birth. It must be noted, though, that for life expectancies at birth ranging from 25 to 32 years, the demographer is faced with three different model systems to choose from, viz.: the New Model for High-Mortality Populations, the Princeton system, and the Hypothetical West African Model (see Figure 3.1).

### *3.4.2 Distributions of Infant-to-child Mortality Relationships*

The next step in this assessment and comparison of model life table systems focuses on under-5 mortality only. As Figure 3.1 indicates, model families and systems show different levels of ${}_5q_0$ at the same level of life expectancy at birth. The focus now shifts to the distribution of deaths within the first five years of life that the model systems depict. Since the Princeton and New United Nations model systems consist of more than one family of model life tables, they provide a wide range of patterns that may accommodate as many different populations as Sub-Saharan Africa presents. It is therefore worthwhile to compare these two systems to decide which is likely to yield better results in the investigation of childhood mortality patterns in Sub-Saharan Africa. The selected system is then compared with the Hypothetical West African model and the New Model for High-Mortality Populations to ascertain the range of distinct childhood mortality patterns they collectively cover.

In many previous studies of childhood mortality patterns in the developing world, interest has focused on the comparison of the distribution of deaths before age 1 year (${}_1q_0$) as against deaths between the exact ages 1 and 5 years (${}_4q_1$) (see, for example, Blacker *et al.*, 1985; Hill, 1995; and Bicego and Ahmad, 1996). These studies adopted different graphical approaches to the investigation of ${}_1q_0$ and ${}_4q_1$ distributions although the interpretations are the same. While Blacker *et al*. (1985) plot ${}_1q_0$ against the corresponding value of ${}_4q_1$, Hill (1995) reverses the axes, i.e. ${}_4q_1$ against ${}_1q_0$, thus making the plots mirror reflections of each other at an angle of 45°. Bicego and Ahmad (1996), on the other hand, considered graphing the ratio ${}_4q_1/{}_5q_0$ against ${}_5q_0$. In this assessment, as well as in the subsequent analysis of childhood mortality patterns in Sub-Saharan Africa, ${}_4q_1$ is considered against the corresponding value of ${}_1q_0$ — the approach Hill (1995) adopted.

Such plots are presented for all levels of mortality covered by the Princeton and New United Nations families of life tables in Figure 3.2 by sex. The Princeton relationships are significantly different from each other. The “North” family is the model pattern with highest child mortality relative to infant mortality for ${}_1q_0$ values of less than about 0.15 for females and 0.16 for males (beyond which it is the “South” in both cases), followed by the “South” and “East” families. The “West” family lies between them.



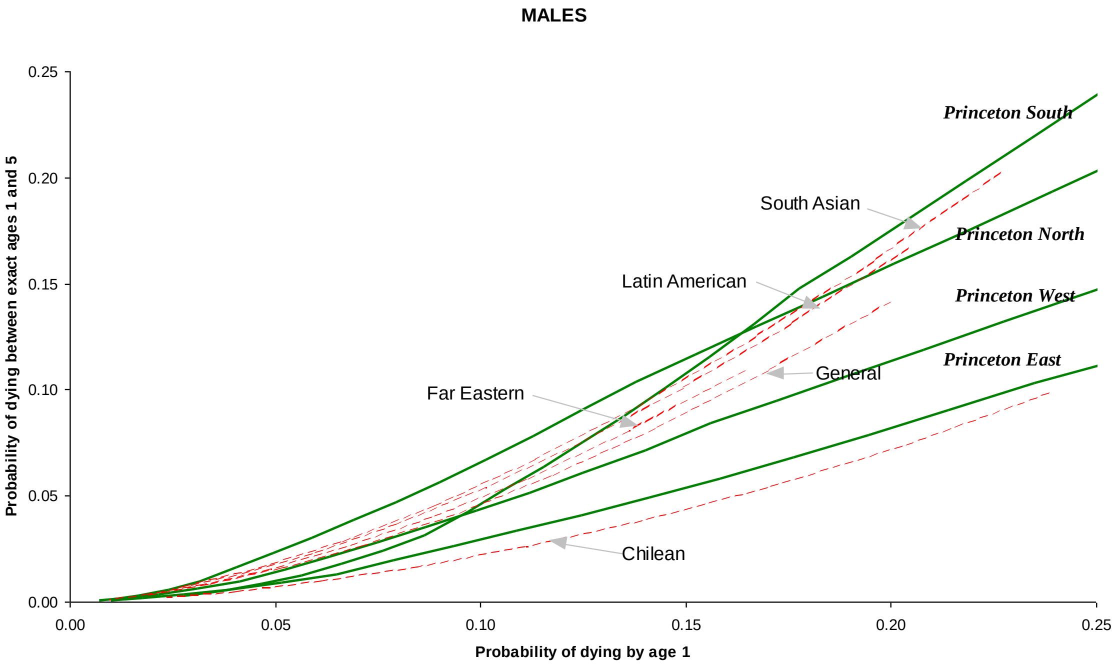




**Figure 3.2:** ***Relationships between child and infant mortality in the four Princeton and five New United Nations model families for females and males.***
***Sources: United Nations (1982b); Coale et al. (1983).***

In the case of the New United Nations system, only the "Chilean" family traces a relationship between child and infant mortality that is significantly different from the other four families of the system. The "South Asian", "Latin American", "Far Eastern" and "General" model families depict infant-to-child mortality relationships that apparently cluster together, especially in the case of males; and appear to be similar to the Princeton "West" pattern at ${}_1q_0$ levels below 0.1, and to the "South" pattern at ${}_1q_0$ levels above 0.1 (see Figure 3.2). The "Chilean" family, on the other hand, depicts low levels of child mortality relative to infant for both males and females, and generally appears to be similar to the Princeton "East" family. It is apparent from Figure 3.2 that the Princeton model life table system presents a much wider range of distinct patterns for use in the investigation of diverse populations than the New United Nations system. Moreover, the New United Nations life tables are not as carefully tailored to demographic estimation as are the Princeton tables (Hobcraft, 1987).

## 3.5 Choice of Model System for Use in the Situation of Sub-Saharan Africa

The distributions of the infant-to-child mortality relationships in the Princeton, Hypothetical West African and Model for High Mortality Population are shown in Figure 3.3. Despite the fact that Sub-Saharan Africa displays the highest mortality levels in childhood in the world, extremely few countries or sub-national populations experience levels of ${}_5q_0$ in excess of 350 per 1,000. The levels depicted by the New Model for High-Mortality Populations in relation to the contours shown in Figure 3.3 range from about 320 to 750 per 1,000, which prove to be too high for most contemporary Sub-Saharan African populations. Besides, the system is a single-family one and working with an average for both sexes would inevitably restrict the entire analysis to a comparison with a single model pattern of childhood mortality. For these reasons, the model system is considered unsuitable for use in the search of childhood mortality in a continent characterised by diversity in almost every aspect of mortality.

With respect to the Hypothetical West African Model, the latter reason forwarded for rejecting the New Model for High-Mortality Populations also applies despite accommodating ${}_5q_0$ levels as low as about 200 per 1,000. Moreover, whilst it may be applicable to some populations in the part of the continent for which it was developed, it unreasonable *a priori* to

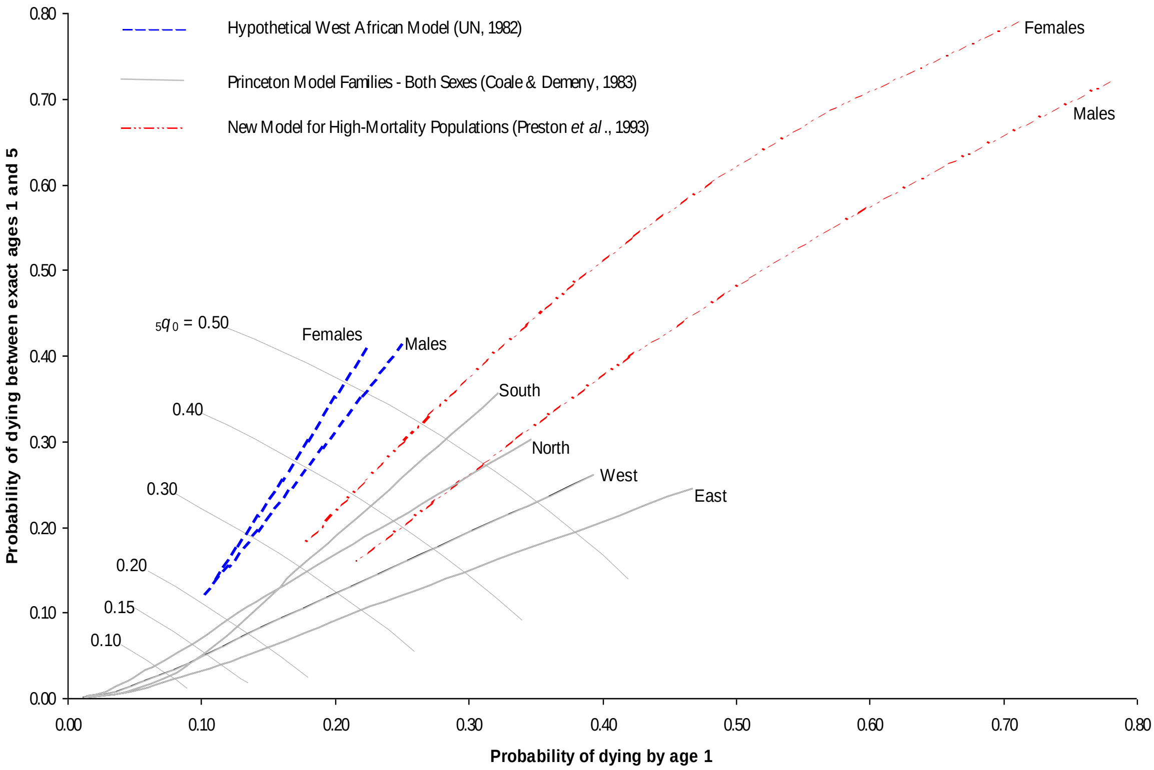



**Figure 3.3:** ***Comparison of child and infant mortality relations in the Hypothetical West African and New Model life tables with those of the four Princeton families; and the corresponding contours of*** $_5q_0$**.**
***Sources: United Nations (1982b); Coale et al. (1983); Preston et al. (1993)***

expect a "West African" model to represent the mortality experience of populations in Eastern and Southern Africa. Being the only model system that presents a spectrum of patterns and covers almost the entire range of $_5q_0$ levels that prevail in the continent — presently as well as in the recent past — the Princeton Model System therefore presents itself as the most appropriate set of life tables to use in the search for prevailing childhood mortality patterns in Sub-Saharan Africa. Figure 3.4 charts the infant-to-child mortality relationships for males, females and both sexes combined for all the Princeton model families of life tables. For any given level of child mortality, the corresponding level of infant mortality is in all cases slightly lower for girls than boys; and that for both sexes combined appears to be the arithmetic mean of the individual levels of the sexes. However, all three categories depict the same patterns in terms of shape.

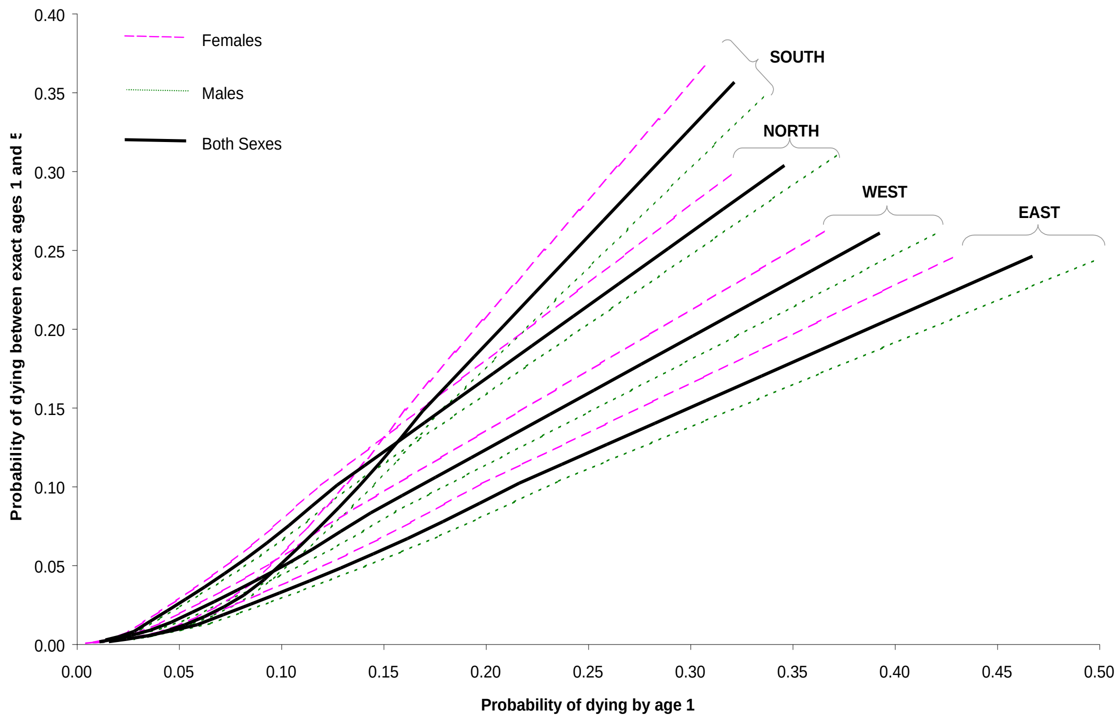



**Figure 3.4:** ***Relationships between child and infant mortality in the four Princeton model families for females, males and both sexes combined.***
***Source: Coale et al. (1983).***

## 3.6 Conclusion

It is apparent from the distributions of infant-to-child mortality depicted by the different model life table systems that the Princeton provides the widest variations in childhood mortality patterns for both sexes. The system also covers the range of overall childhood mortality levels that prevail in contemporary African populations, thus making it more appropriate for the investigation of childhood mortality patterns in the continent. Since the depicted distributions for sexes are slightly different, the question to ask is how significant are sex differentials in childhood mortality patterns as far as Sub-Saharan Africa is concerned? In their study of general mortality patterns in rural Senegal using high quality longitudinal data, Pison and Langaney (1985) report that there is no evidence of sex differentials in mortality patterns in childhood and adulthood. LeGrand and Mbacké (1995) further buttress this finding in their assessment of sex differences in mortality among children in two urban centres and one rural area in Sahel West Africa. They conclude that there were no significant differences between male and female mortality risks between the ages 1 and 23 months in any of the areas considered. Although this evidence is insufficient to cover the whole of Sub-Saharan Africa with respect to sex differentials in childhood mortality patterns, one cannot but consider adopting the average infant-to-child mortality relationships traced out by “Both Sexes Combined” in the Princeton model system for ease of analysis.

# Chapter 4

# Data Quality, Recent Levels and Trends in Childhood Mortality

4

## 4.1 Introduction

Two preparatory tasks are required prior to the examination of age patterns of mortality in childhood in Sub-Saharan Africa using birth histories from Demographic and Health Surveys. These tasks are:

a. a thorough assessment of the quality of the mortality data contained in the birth histories from the respective national Demographic and Health Surveys;

b. description of the recent levels and trends in childhood mortality at the national level.

Internal and external data consistency checks can identify potential errors which analysis of age patterns of mortality may be sensitive to. As far as birth histories are concerned, such errors reflect “recall” difficulties and include omission of dead children, especially those who died at very early ages and at remote periods in the past before the survey; and displacement of birth and death dates. Both forms of error usually become more frequent for increasing periods of time before the survey. With respect to age patterns of mortality, omission of dead children leads to under-estimates of mortality at more remote periods prior to the survey, thereby increasing the likelihood of observing unusual or anomalous mortality patterns at the extremes of the time-span to which estimates refer. Shifts of birth and death dates, on the other hand, can greatly influence age patterns of mortality derived from birth histories, especially in instances where probabilities of death are computed over short age intervals. Deaths among a specific birth cohort displaced from a particular calendar period to an earlier or later one will inevitably under-estimate or over-estimate survivorship, and consequently depict a deceptive age pattern of mortality.

It is widely contended that mortality patterns in childhood change with level of mortality. The experience of most Sub-Saharan African countries is of a gradual transition from high to relatively lower levels of childhood mortality in the second half of the last century. Thus, a thorough understanding of the trends in childhood mortality in the continent is pertinent in the assessment of age patterns of mortality within the first five years of life. This chapter therefore sets out to assess the childhood mortality indicators directly estimated from birth histories contained in all DHS data sets for each of the countries included in the study. These estimates are compared with estimates derived using indirect techniques to assess their internal consistency. Resulting estimates are further subjected to external checks by comparing them with others obtained from different sources such as censuses and national surveys. Finally a description of childhood mortality trends at national and sub-regional levels over the past four decades is attempted.

## 4.2 Method of Direct Estimation of Childhood Mortality

By their nature, indirect techniques of mortality estimation yield no information relevant in the assessment of age patterns of mortality. Directly derived childhood mortality measures from birth history data, on the other hand, provide the opportunity of deriving childhood mortality measures over a range of age intervals by calendar periods, by birth order, for specific birth cohorts, etc, thus enabling the assessment of age patterns of mortality. A procedure of direct mortality estimation first proposed by Somoza (1980) and later modified by Rutstein (1984) uses the life table approach to estimate probabilities of dying between two exact ages. The probabilities are based on the number of deaths among children in a specified age range during a specified calendar period, with children of different birth cohorts contributing to the exposure and mortality experience thus enabling the derivation of a period-specific, age-specific probability estimate. Such probabilities are computed for a range of age intervals over the calendar period in question. The age intervals used are: less than 1 month, 1-2 months, 3-5 months, 6-11 months, 12-23 months, 24-35 months, 36-47 months, and 48-59 months. For each age interval, the probability of dying is obtained by dividing the number of deaths occurring in that interval among children of that age who were exposed to death in that calendar period, by the number of children exposed.

From the Lexis chart below (see Figure 4.1), it is clear that for any given calendar period $t_1$ to $t_2$, there are three groups of children between the ages *a* and *b* who are exposed to death. These are:

i. children born between $t_1$-*a* and $t_2$-*b*, i.e. those aged *a* years at time $t_1$ and *b* years at time $t_2$;
ii. children born between $t_1$-*a* and $t_1$-*b;* and
iii. children born between $t_2$-*a* and $t_2$-*b*.

Children in the first group, represented by the parallelogram *ABCD*, were exposed during the entire period $t_1$ to $t_2$. Those in the second and third groups were exposed only for parts of the period represented by the triangles *ADH* and *BFC* respectively. Since the age intervals considered are reasonably short, especially in the first year of life where mortality is highest for most populations, it is assumed that half of the deaths and exposure among children of the two latter groups occurred within the period $t_1$ to $t_2$.

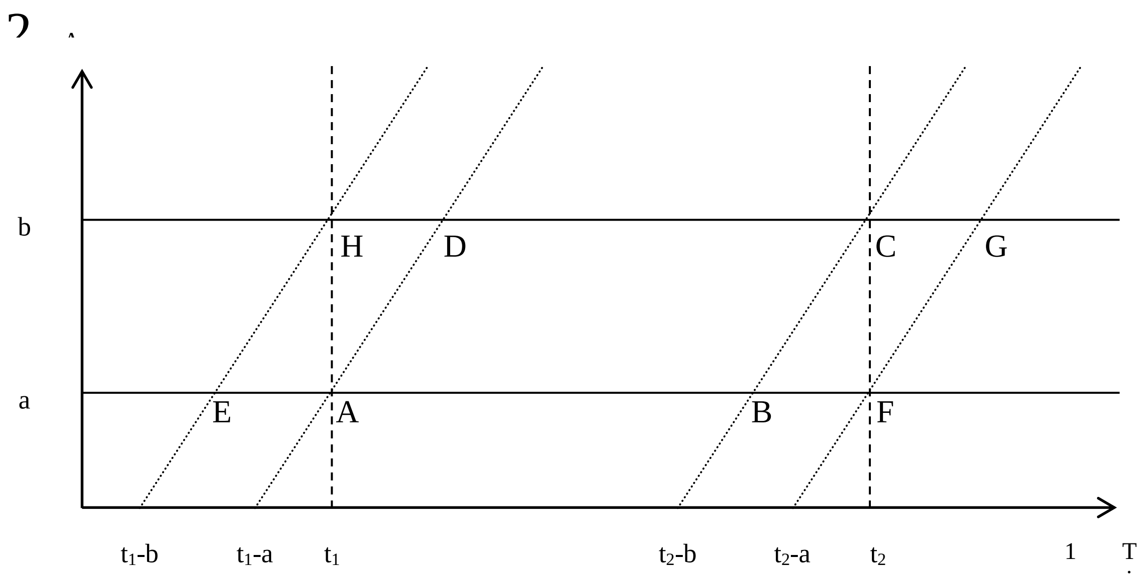



**Figure 4.1:** ***Cohorts used to calculate synthetic rates.***

Denote the number of deaths that occur among children in the first group $d_1$, and those in the second and third groups $d_2$ and $d_3$ respectively. If there is a total of $N_1$, $N_2$ and $N_3$ children in the respective groups, then by definition, the probability of dying between exact ages $a$ and $b$ within the period $t_1$ to $t_2$, is given by

$$_{b-a}q_a = \frac{d_1 + \frac{1}{2}(d_2 + d_3)}{N_1 + \frac{1}{2}(N_2 + N_3)}.$$

However, in the special case where time $t_2$ happens to be the date at which the survey was conducted, all the deaths among children born between $t_2$-$a$ and $t_2$-$b$ must have occurred before time $t_2$. Therefore, all the deaths among children in the third group are counted despite having been exposed for only half the period. Thus the probability of dying between exact ages $a$ and $b$ in this case is

$$_{b-a}q_a = \frac{d_1 + \frac{1}{2}d_2 + d_3}{N_1 + \frac{1}{2}N_2 + N_3}.$$

Such probabilities are derived for each age interval mentioned — i.e. from less than a month through to 48-59 months. Then conventional probabilities of death between any two exact ages that range between birth and age 5 are calculated as the complement of the product of the probabilities of surviving the relevant sub-intervals. Thus if the probability of dying within a relevant age sub-interval is denoted $q[i]$, then any required probability of death within the conventional measures of childhood mortality, $_nq_x$, is given by

$$_nq_x = 1 - \prod_{i=x}^{i=x+n}(1 - q[i]).$$

Using this technique, six conventional probabilities that depict childhood mortality are

derived for each of the countries included in the study. These are:

i. neonatal mortality, the probability of dying between birth and exact age one month;
ii. infant mortality, the probability of dying between birth and exact age one year ($_1q_0$);

iii. child mortality, the probability of dying between exact ages one and five ($_4q_1$);
iv. early child mortality, the probability of dying between exact ages one and two years ($_1q_1$);
v. late child mortality, the probability of dying between exact ages two and five ($_3q_2$); and
vi. under-five mortality, the probability of dying between birth and exact age five years ($_5q_0$).

A seventh measure of childhood mortality, post-neonatal mortality, is also included. Unlike the above six measures, the post-neonatal mortality rate is not a probability, but rather the arithmetic difference between the infant mortality rate and the neonatal mortality rate.

## 4.3 Recent Levels of Childhood Mortality in Sub-Saharan Africa

For the ease of presentation, recent levels of childhood mortality are reported according to sub-regions of the continent as defined in Chapter 1. Estimates were derived by quinquennia for up to 25 years prior to each survey in every country. The whole series of estimates are presented in Appendix 2, and only the most recent ones are discussed in this section.

### *4.3.1 Sahel West Africa*

Each country in this sub-continental region has at least two DHS data sets from which recent levels of child mortality can be estimated directly for different reference periods. This makes it possible to compare national child mortality estimates for the same country at different times and between countries at similar reference periods. The recent estimates of child mortality measures derived from the eight DHS data sets for the four countries are presented in Table 4.1 by reference date.

**Table 4.1:** ***National level child mortality indicators and relative risk of dying in Sahel West African countries by reference period.***

| Country | Date | NNM | PNNM | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|---|
| ***Recent Childhood Mortality Rates (deaths per 1,000)*** | | | | | | | | |
| Senegal | *1984.25* | 45.8 | 42.0 | 87.8 | 44.7 | 75.9 | 117.2 | 194.7 |
| | *1991.17* | 34.4 | 33.2 | 67.6 | 22.8 | 46.5 | 68.2 | 131.2 |
| | *1994.92* | 37.3 | 30.3 | 67.6 | 27.4 | 50.4 | 76.3 | 138.8 |
| Mali | *1985.17* | 51.1 | 53.7 | 104.8 | 56.2 | 108.7 | 158.7 | 246.9 |
| | *1993.92* | 60.3 | 62.1 | 122.4 | 48.7 | 86.7 | 131.2 | 237.5 |
| Burkina Faso | *1990.83* | 43.2 | 50.5 | 93.6 | 43.2 | 62.3 | 102.8 | 186.8 |
| | *1996.58* | 40.8 | 64.6 | 105.3 | 48.0 | 83.2 | 127.1 | 219.1 |
| Niger | *1990.00* | 40.8 | 82.2 | 123.0 | 87.6 | 147.6 | 222.3 | 317.9 |
| | *1996.08* | 44.2 | 78.8 | 123.1 | 70.5 | 108.9 | 171.7 | 273.7 |
| ***Relative risk of dying, 1990-1991 (Reference: Senegal, 1991.17)*** | | | | | | | | |
| Senegal | *1991.17* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Burkina Faso | *1990.83* | 1.26 | 1.52 | 1.38 | 1.89 | 1.34 | 1.51 | 1.42 |
| Niger | *1990.00* | 1.19 | 2.48 | 1.82 | 3.84 | 3.17 | 3.26 | 2.42 |
| ***Relative risk of dying, 1993-1996 (Reference: Senegal, 1994.92)*** | | | | | | | | |
| Senegal | *1994.92* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Mali | *1993.92* | 1.62 | 2.05 | 1.81 | 1.78 | 1.72 | 1.72 | 1.71 |
| Burkina Faso | *1996.58* | 1.09 | 2.13 | 1.56 | 1.75 | 1.65 | 1.67 | 1.58 |
| Niger | *1996.08* | 1.18 | 2.60 | 1.82 | 2.57 | 2.16 | 2.25 | 1.97 |

Sources: *National Demographic and Health Surveys.*

The reference dates for the most recent estimates of childhood mortality indicators in these four Sahelian countries range from 1993 for Mali to 1996 for Niger and Burkina Faso. For the periods for which estimates are available, no country in this region has an under-five mortality rate of less than 130 per 1,000, or an infant mortality rate of less than 65 per 1,000. Generally, childhood mortality is lightest in Senegal and severest in Niger. The probability of dying between exact ages 1 and 5 is consistently higher than that of dying in infancy in all four countries, although only slightly so in Senegal at recent periods. Mali and Niger recorded infant mortality levels of more than 100 per 1,000 and under-five mortality of more than 200 per 1,000. Estimates for the most recent periods show that infant mortality rates ranged from about 68 per 1,000 in Senegal towards the end of 1994 to 123 per 1,000 in Niger in 1996; with under-five mortality levels ranging from just under 140 per 1,000 to about 274 per 1,000 in the same countries at the same times.

While under-five mortality in Burkina Faso was 42% higher than in Senegal at the beginning of the last decade, it was about 2.4 times the 1991 Senegalese level in Niger. Neonatal mortality rates for the same periods were more or less similar in these three countries. However, the derived relative risks of deaths indicate that whilst Burkinabe infants had 50% greater risk of dying between 2 and 11 months of age than their Senegalese counterparts, those in Niger had about 150% greater risk of dying in the same age bracket. As a result, infant mortality rates were 38% and 82% higher in Burkina Faso and Niger respectively than that recorded in Senegal in 1991. Similarly, the probability of dying between the exact ages 1 and 5 years was 1.5 times the Senegalese level in Burkina Faso, compared with about 3.3 times the same Senegalese level in Niger (see Table 4.1).

Using the 1994 childhood mortality rate estimates for Senegal as reference, the relative risk of dying in infancy remained virtually unchanged for children in Niger. This is to be expected, since both countries maintained the same levels of infant mortality during the first half of that decade. However, the Senegalese estimates from the second and third phase DHS surveys suggest a slight increase of 12% in child mortality, i.e. the probability of dying between exact ages 1 and 5, ${}_4q_1$. Similar estimates for Niger record a substantial decrease of 23% in child mortality between 1990 and 1996. Notwithstanding, ${}_4q_1$ in Niger in 1996 was 2.25 times the level recorded in Senegal about a year earlier.

In the case of Mali, infant mortality at the end of 1993 was 80% higher than in Senegal exactly a year later; and under-five mortality was 70% above the Senegalese level at the same time. Even though the most recent rates for Mali and Niger refer to time periods that differ by two years, it is quite clear from the estimates that infant mortality rates were similar in the two countries in the first half of the last decade. Under-five mortality, on the other hand, differed between the two countries — it was 71% and 97% more than the 1995 Senegalese level in Mali and Niger respectively. The Malian child mortality rate at the start of 1994 was 72% higher than the Senegalese rate at the start of 1995; whilst that of Niger at the start of 1996 was 125% more than the 1995 Senegalese rate. It is clear that age patterns of mortality in childhood differ significantly among these national populations, and that they change with time.

### *4.3.2 Coastal West Africa*

This region forms a contiguous geographical entity that spans the Western African coast from Guinea in the west to Nigeria in the east. The most recent estimates of childhood mortality for the seven constituent countries are presented in Table 4.2. Liberia is the only country in the region without childhood mortality estimates in the 1990s, whereas estimates referring to periods earlier than 1990 are not available for Guinea, Côte d'Ivoire and Benin. With the exception of Liberia, no country in this region has recorded under-five mortality levels in excess of 200 per 1,000, or infant mortality rate of more than 100 per 1,000.

Under-five mortality estimates range from 107 per 1,000 in Ghana in 1996 to 177 per 1,000 in Guinea in 1997 if estimates within the last decade only are considered; and up to 220 per 1,000 if the 1984 Liberian estimates are included. Similarly, infant mortality ranged from just under 60 per 1,000 in Ghana in 1996 to 98 per 1,000 in Guinea in 1997; and just over 140 per 1,000 in Liberia in 1984. Unlike the Sahelian countries, the most recent childhood mortality indicators show that these coastal West African countries are characterised by slightly lower child mortality than infant mortality in the 1990s. The Sahelian pattern, however, prevailed in Ghana and Togo in the mid-1980s. This presents further evidence that age patterns of mortality in childhood vary with changing mortality levels over time.

In the mid-1980s, i.e. the period for which the Liberian estimates refer to, childhood mortality levels and patterns were similar in the two neighbouring countries of Ghana and Togo as depicted by the relative risk of dying between 1984 and 1986 using Ghana's 1995 rates as reference (see Table 4.2). In 1984, Liberia recorded infant and under-five mortality levels that were 85% and 42% more than the Ghanaian levels respectively. This therefore suggests a geographical pattern of heavier childhood mortality in the western part of the region and relatively lighter mortality in the eastern part around the mid-1980s.

**Table 4.2:** ***National level child mortality indicators and relative risk of dying in Coastal West African countries by reference period.***

| Country | Date | NNM | PNNM | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|---|
| ***Recent Childhood Mortality Rates (deaths per 1,000)*** | | | | | | | | |
| Guinea | *1997.17* | 48.4 | 49.6 | 98.0 | 34.8 | 54.6 | 87.5 | 176.9 |
| Liberia | *1984.17* | 67.2 | 75.2 | 142.4 | 48.6 | 44.1 | 90.6 | 220.1 |
| Côte d'Ivoire | *1992.42* | 42.0 | 46.5 | 88.5 | 27.1 | 41.0 | 66.9 | 149.5 |
| Ghana | *1985.92* | 43.3 | 33.7 | 77.0 | 29.7 | 56.0 | 84.0 | 154.5 |
| | *1991.67* | 40.6 | 25.6 | 66.2 | 20.9 | 36.6 | 56.8 | 119.2 |
| | *1996.67* | 29.7 | 27.1 | 56.7 | 19.5 | 34.4 | 53.2 | 106.9 |
| Togo | *1986.42* | 39.7 | 37.6 | 77.3 | 27.7 | 57.3 | 83.4 | 154.3 |
| | *1995.92* | 41.1 | 38.2 | 79.3 | 22.6 | 50.8 | 72.3 | 145.8 |
| Benin | *1994.17* | 38.2 | 55.8 | 93.9 | 31.3 | 50.2 | 79.9 | 166.3 |
| Nigeria | *1988.50* | 42.2 | 45.2 | 87.4 | 42.6 | 76.1 | 115.5 | 192.8 |
| | *1996.92* | 36.9 | 38.3 | 75.2 | 28.2 | 43.4 | 70.3 | 140.2 |
| ***Relative risk of dying, 1984-1986 (Reference: Ghana, 1985.92)*** | | | | | | | | |
| Ghana | *1985.92* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Liberia | *1984.17* | 1.55 | 2.23 | 1.85 | 1.64 | 0.79 | 1.08 | 1.42 |
| Togo | *1986.42* | 0.92 | 1.12 | 1.00 | 0.93 | 1.02 | 0.99 | 1.00 |
| ***Relative risk of dying, 1988-1992 (Reference: Ghana, 1991.67)*** | | | | | | | | |
| Ghana | *1991.67* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Côte d'Ivoire | *1992.42* | 1.03 | 1.82 | 1.34 | 1.30 | 1.12 | 1.18 | 1.25 |
| Nigeria | *1988.50* | 1.04 | 1.77 | 1.32 | 2.04 | 2.08 | 2.03 | 1.62 |
| ***Relative risk of dying, 1994-1997 (Reference: Ghana, 1996.67)*** | | | | | | | | |
| Ghana | *1996.67* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Guinea | *1997.17* | 1.63 | 1.83 | 1.73 | 1.78 | 1.59 | 1.64 | 1.65 |
| Togo | *1995.92* | 1.38 | 1.41 | 1.40 | 1.16 | 1.48 | 1.36 | 1.36 |
| Benin | *1994.17* | 1.29 | 2.06 | 1.66 | 1.61 | 1.46 | 1.50 | 1.56 |
| Nigeria | *1996.92* | 1.24 | 1.41 | 1.33 | 1.45 | 1.26 | 1.32 | 1.31 |

Sources: *National Demographic and Health Surveys.*

By 1995-97, however, childhood rates were much lower in Ghana than in Togo, although the age patterns of mortality remain very much the same, as suggested by the relative risks of dying in the bottom panel of Table 4.2. Further east, Benin had slightly higher childhood mortality in 1994 than both Ghana and neighbouring Togo. Infant mortality in this state was 1.66 times the Ghanaian level in 1996; whilst 56% more of children under the age of five die than in Ghana at the same specified periods. To the west of Ghana, Côte d'Ivoire shows slightly higher childhood mortality relative to Ghana during the 1991-2 period, 34% higher infant mortality and 25% higher under-five mortality. Both countries had similar levels of neonatal mortality and the relatively high post-neonatal mortality rate in Côte d'Ivoire accounts for the observed difference in infant mortality between the two countries.

### *4.3.3 Middle Africa*

The childhood mortality levels for the three countries from this region are tabulated in Table 4.3. Only Cameroon has more than one set of estimates. The estimates of under-five mortality

**Table 4.3:** ***National level child mortality indicators and relative risk of dying in Middle African countries by reference period.***

| Country | Date | NNM | PNNM | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|---|
| ***Recent Childhood Mortality Rates (deaths per 1,000)*** | | | | | | | | |
| Cameroon | *1989.33* | 32.8 | 31.5 | 64.3 | 29.8 | 36.5 | 65.2 | 125.3 |
| | *1996.30* | 37.2 | 39.8 | 77.0 | 31.9 | 49.6 | 79.9 | 150.7 |
| C A R | *1992.75* | 42.1 | 54.6 | 96.7 | 26.0 | 42.4 | 67.3 | 157.5 |
| Chad | *1995.08* | 43.9 | 58.5 | 102.4 | 41.8 | 62.9 | 102.0 | 194.0 |
| ***Relative risk of dying, 1989-1996 (Reference: Cameroon, 1989.33)*** | | | | | | | | |
| Cameroon | *1989.33* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| C A R | *1992.75* | 1.28 | 1.73 | 1.50 | 0.87 | 1.16 | 1.03 | 1.26 |
| Chad | *1995.08* | 1.34 | 1.86 | 1.59 | 1.40 | 1.72 | 1.56 | 1.55 |
| Cameroon | *1996.30* | 1.13 | 1.26 | 1.20 | 1.07 | 1.36 | 1.23 | 1.20 |

Sources: *National Demographic and Health Surveys.*

range from of 125 per 1,000 in Cameroon in 1988 to 194 per 1,000 in Chad in 1995. Infant mortality, on the other hand, ranged from just under 65 per 1,000 in Cameroon to about 100 per 1,000 in Central African Republic and Chad, referring to dates a little over two years apart. It is clear that infant mortality rates were similar to child mortality rates in Cameroon from the end of the 1980s to the mid-1990s, and in Chad in 1995; whereas infant mortality was relatively higher than child mortality in the Central African Republic in 1992.

Although infant and under-five mortality levels in Central African Republic and Chad have not fallen to the level attained by Cameroon in 1989, every aspect of childhood mortality registered an increase in Cameroon according to the country's 1996 estimates. Notwithstanding, the geographical pattern of childhood mortality in this region remains one that increases northwards from Cameroon.

### *4.3.4 Eastern Africa*

Three of the six countries in this sub-continental region have at least two sets of childhood mortality estimates, i.e. Kenya, Uganda and Tanzania. However, only Kenya and Tanzania have two sets of estimates with reference dates within the last decade. Generally, recent levels of under-five mortality in this region lie between the 112 per 1,000 mark in Kenya in 1996 and 166 per 1,000 in Ethiopia in 1998 (see Table 4.4). Uganda's level in 1986 was as high as 176 per 1,000, but its estimate for 1993 shows a drop to a little under 150 per 1,000. Infant mortality rates for the same recent reference dates range from 74 per 1,000 in Kenya in 1996 to 99 per 1,000 in Tanzania in 1997, and 97 per 1,000 in Ethiopia in 1998.

Despite having the lowest levels of childhood mortality in the region for the periods considered — with under-five mortality rates of less than 100 per 1,000 at the latter part of the 1980s and the early 1990s — the surveys suggest that childhood mortality has been increasing in Kenya recently. Those for Tanzania and Uganda suggest slightly declining mortality. This is evident from the estimated relative risks of death at the second and third panels of Table 4.4. While infant and child mortality levels in Uganda were respectively about 60% and 140% over the Kenyan levels in 1990/1991, excess deaths in Uganda relative to Kenya dropped to

**Table 4.4:** ***National level child mortality indicators and relative risk of dying in Eastern African countries by reference period.***

| Country | Date | NNM | PNNM | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|---|
| ***Recent Childhood Mortality Rates (deaths per 1,000)*** | | | | | | | | |
| Kenya | *1986.92* | 27.1 | 32.8 | 59.9 | 14.0 | 16.7 | 30.5 | 88.5 |
| | *1991.17* | 25.7 | 35.9 | 61.7 | 15.3 | 21.7 | 36.6 | 96.0 |
| | *1996.08* | 28.4 | 45.3 | 73.7 | 19.9 | 21.3 | 40.8 | 111.5 |
| Uganda | *1986.67* | 42.5 | 55.0 | 97.5 | 38.4 | 50.7 | 87.1 | 176.1 |
| | *1993.17* | 27.0 | 54.3 | 81.3 | 32.6 | 40.8 | 72.0 | 147.4 |
| Tanzania | *1990.00* | 37.9 | 53.4 | 91.3 | 20.4 | 34.6 | 54.3 | 140.7 |
| | *1994.42* | 31.7 | 55.6 | 87.3 | 23.3 | 31.1 | 53.6 | 136.3 |
| | *1997.42* | 40.4 | 58.7 | 99.1 | 25.2 | 28.2 | 52.7 | 146.6 |
| Rwanda | *1990.33* | 38.6 | 46.3 | 85.0 | 22.6 | 50.6 | 72.0 | 150.8 |
| Burundi | *1985.17* | 35.2 | 38.5 | 73.7 | 27.7 | 59.0 | 85.1 | 152.5 |
| Ethiopia | *1998.00* | 48.7 | 48.3 | 97.0 | 28.5 | 49.5 | 76.7 | 166.2 |
| ***Relative risk of dying, 1990-1991 (Reference: Kenya, 1991.17)*** | | | | | | | | |
| Kenya | *1991.17* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Tanzania | *1990.00* | 1.47 | 1.49 | 1.48 | 1.33 | 1.59 | 1.48 | 1.47 |
| Rwanda | *1990.33* | 1.50 | 1.29 | 1.38 | 1.48 | 2.33 | 1.97 | 1.57 |
| Uganda | *1986.67* | 1.65 | 1.53 | 1.58 | 2.51 | 2.34 | 2.38 | 1.83 |
| ***Relative risk of dying, 1993-1997 (Reference: Kenya, 1996.08)*** | | | | | | | | |
| Kenya | *1996.08* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Tanzania | *1994.42* | 1.12 | 1.23 | 1.18 | 1.17 | 1.46 | 1.31 | 1.22 |
| Tanzania | *1997.42* | 1.42 | 1.30 | 1.34 | 1.27 | 1.32 | 1.29 | 1.31 |
| Uganda | *1993.17* | 0.95 | 1.20 | 1.10 | 1.64 | 1.92 | 1.76 | 1.32 |
| Ethiopia | *1998.00* | 1.71 | 1.07 | 1.32 | 1.43 | 2.32 | 1.88 | 1.49 |

Sources: *National Demographic and Health Surveys.*

only 10% and 76% for infants and children aged 1 to 4 years by the mid-1990s. The explanation for this is the recent increasing childhood mortality in Kenya and decreasing levels in Tanzania. In Rwanda, the excess mortality over the Kenyan level during the same period was 38% for infants and 97% for children 1 to 4 years of age. Ugandan childhood mortality in 1993 was about 20% higher than in Kenya in 1996. Despite these differences in childhood mortality levels, the relative risks of dying suggest that age patterns of mortality among these national populations may not differ significantly.

### *4.3.5 Southern Africa*

The countries with the lowest under-five mortality in recent periods for which data are available fall in the Southern region of the continent. Other countries with levels higher than those of most West African countries are also found in the region. Zimbabwe and Namibia recorded very similar low levels of infant and under-five mortality in the early part of the 1990s; whereas Zambia and Mozambique, at the other extreme, exhibited high levels of childhood mortality in the mid-1990s (see Table 4.5).

Recent estimates of under-five mortality rates in the region range from 59 per 1,000 in South Africa in 1995 to a little under 200 per 1,000 in Mozambique in the same year, but more than 230 per 1,000 in Malawi in 1990. Infant mortality, on the other hand, was only 45 per 1,000 in South Africa and over 130 per 1,000 in Mozambique in 1995, and in Malawi in 1990. It is apparent from these figures that childhood mortality in Zambia at the beginning of the last decade was more than twice as high as in Namibia in the southwest. Under-five mortality rates in Zambia and Mozambique at the latter part of 1994 were 2½ times neighbouring Zimbabwe's 1992 level. However, estimates from previous surveys indicate recent increases in childhood mortality in Zimbabwe and Zambia, similar to those observed in Kenya.

As in Eastern Africa, levels of child mortality in these southern African countries have consistently been lower than infant mortality levels. This implies an age pattern of childhood mortality somewhat similar to those of the eastern region countries, but different from those of the Sahel and most Coastal West African countries. Furthermore, age patterns of mortality differ significantly among the six Southern African countries. For instance, while infant mortality rates were more than twice the earlier levels of Zimbabwe and Namibia, the risk of dying between exact ages 1 and 5 in Zambia and Mozambique were about 4 and 3 times respectively relative to the Zimbabwean and Namibian levels. Notwithstanding this, the recent

**Table 4.5:** ***National level child mortality indicators and relative risk of dying in Southern African countries by reference period.***

| Country | Date | NNM | PNNM | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|---|
| ***Recent Childhood Mortality Rates (deaths per 1,000)*** | | | | | | | | |
| South Africa | *1995.80* | 19.8 | 25.6 | 45.4 | 8.5 | 6.3 | 14.7 | 59.4 |
| Zimbabwe | *1986.58* | 26.6 | 22.4 | 49.1 | 13.0 | 9.7 | 22.5 | 70.5 |
| | *1992.42* | 24.1 | 28.4 | 52.5 | 14.5 | 11.3 | 25.6 | 76.8 |
| | *1997.50* | 28.9 | 36.2 | 65.0 | 18.7 | 21.3 | 39.6 | 102.1 |
| Zambia | *1989.92* | 42.5 | 64.7 | 107.2 | 52.7 | 43.6 | 94.0 | 191.1 |
| | *1994.58* | 35.2 | 73.5 | 108.7 | 50.6 | 50.2 | 98.2 | 196.2 |
| Mozambique | *1995.08* | 53.5 | 79.3 | 132.8 | 20.1 | 56.4 | 75.4 | 198.2 |
| Malawi | *1990.42* | 41.2 | 93.5 | 134.6 | 51.1 | 66.8 | 114.5 | 233.8 |
| Namibia | *1990.42* | 30.9 | 24.9 | 55.8 | 11.8 | 16.8 | 28.4 | 82.7 |
| ***Relative risk of dying, 1989-1990 (Reference: Namibia, 1990.42)*** | | | | | | | | |
| Namibia | *1990.42* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Zambia | *1989.92* | 1.38 | 2.60 | 1.92 | 4.47 | 2.60 | 3.31 | 2.31 |
| Malawi | *1990.42* | 1.33 | 3.76 | 2.41 | 4.33 | 3.98 | 4.03 | 2.83 |
| ***Relative risk of dying, 1992-1997 (Reference: Zimbabwe, 1992.42)*** | | | | | | | | |
| Zimbabwe | *1992.42* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Zambia | *1994.58* | 1.46 | 2.59 | 2.07 | 3.49 | 4.44 | 3.84 | 2.55 |
| Mozambique | *1995.08* | 2.22 | 2.79 | 2.53 | 1.39 | 4.99 | 2.95 | 2.58 |
| South Africa | *1995.80* | 0.82 | 0.90 | 0.86 | 0.59 | 0.56 | 0.57 | 0.77 |
| Zimbabwe | *1997.50* | 1.20 | 1.27 | 1.24 | 1.29 | 1.88 | 1.55 | 1.33 |

Sources: *National Demographic and Health Surveys.*

levels of $_4q_1$ in Zambia and Mozambique are significantly lower than those estimated for all Sahel West African countries except for Senegal.

Generally, the derived childhood mortality levels covering recent periods for the countries concerned appear to be plausible. The levels reported in the regional clusters concur with patterns reported in earlier studies by Hill (1993) using indirect estimation methods. Among the consistent features reported by Hill are the relatively lower levels of under-five mortality in the Eastern and Southern regions than in the West of the continent. Notwithstanding, it would be erroneous to accept the demographic picture that these estimates portray without subjecting them to tests to ascertain their validity and reliability for use in further demographic analyses. This task is undertaken in the ensuing section of this chapter.

## 4.4 Assessment of Estimated Levels of Child Mortality

### *4.4.1 Data Checks*

The authenticity of the ${}_5q_0$ estimates and the trends that they collectively depict for a specific population depend entirely on the quality of the information from which they are derived. As a result, it is important to carry out a few tests to establish whether, even if the data is not of perfect quality, potential errors have been kept to a reasonable minimum. Child mortality data from surveys of the first and second phases of the DHS programme have been assessed and confirmed as generally of good quality by Sullivan *et al.* (1990) and Curtis (1995). Here, two tests are performed to assess in the direct estimates of ${}_5q_0$ obtained.

a. Indirectly estimated levels of ${}_5q_0$ from information on children ever born and children surviving from the same survey are used to assess the trend in the direct estimates covering the 15-year period prior to each survey. This is an internal test since different data types from the same source are analysed in different ways to generate two sets of ${}_5q_0$ estimates that should depict the same levels and trend over at least fifteen years before the survey.

b. Other direct and/or indirect estimates of ${}_5q_0$ obtained from data collected in different inquiries are compared with the childhood mortality levels and trends portrayed by the estimates obtained directly from the DHS data. This is the external test. These enquiries are mainly of the form of censuses or national demographic sample surveys.

### 4.4.2 Indirect Estimation of Childhood Mortality

The indirect technique of estimating child mortality was first proposed by Brass (1964) and is still one of the most widely used methods of estimating childhood mortality in countries characterised by a scarcity of relevant data for direct estimation of mortality. The technique is based on responses to two retrospective questions put to women in demographic enquiries in addition to the question that establishes their ages at the time of the enquiry. The retrospective questions concern:

i. the number of live-born children they have given birth to; and
ii. the number of those children that have survived.

Suppose at the time of an enquiry, women in age-group $i$ reported having ever born $B_i$ children, and out of whom $D_i$ died. Then the proportion dead of children ever born to women aged $i$ is given by

$$d_i = \frac{D_i}{B_i}. \qquad \text{—— (1)}$$

Alternatively, the number of dead children can be regarded as a function, $D_i(a)$, of the distribution of births in the life histories of the women, $B_i(a)$, and the level of mortality, $q(a)$, such that

$$D_i(a) = B_i(a) \cdot q(a), \qquad \text{—— (2)}$$

where $a$ represents the period in years since the birth of the children. This implies that equation (1) can be written in the form

$$d_i = \frac{\int_0^{i-\alpha} D_i(a)da}{\int_0^{i-\alpha} B_i(a)da}, \qquad \text{——(3)}$$

where $\alpha$ is the earliest age at which childbearing can begin. Introducing the neutral value of $B_i(a)/B_i(a)$ in the numerator of equation (3) and drawing from the relationship in equation (2), it necessarily follows that

$$d_i = \frac{\int_0^{i-\alpha} B_i(a) \cdot \frac{D_i(a)da}{B_i(a)}}{\int_0^{i-\alpha} B_i(a)da}$$

$$= \frac{\int_0^{i-\alpha} B_i(a) \cdot q(a)da}{B_i}$$

$$= \int_0^{i-\alpha} c_i(a) \cdot q(a)da, \qquad \text{——(4)}$$

where $c_i(a)$ is the proportion of births to women aged $i$ that occurred $a$ years earlier, i.e. $B_i(a)/B_i$. It is apparent, from equation (4), that $d_i$ is a weighted average of $q(a)$, the weights being the time distribution of births in the past of women aged $i$ at the time of the survey. Since older women are expected to have higher number of births that would have occurred much longer ago, $d_i$ must necessarily be directly proportional to the age of women. Using the mean value theorem in equation (4) yields

$$d_i = \int_0^{i-\alpha} c_i(a) \cdot q(a)da \quad = q(a') \cdot \int_0^{i-\alpha} c_i(a)da \quad = q(a'), \qquad \text{——(5)}$$

where $a'$ is a specific age (between 0 and $i$-$\alpha$) of children born to women aged $i$ at the time of the survey at which $d_i = q(a')$. It was on the basis of this that Brass (1964) established a set of correspondences between the age of women, $i$, and the age of children, $a'$, whose mortality is most precisely identified by reports of these women. He proposed approximate correspondences as shown in Table 4.6 below. In essence, it is contended that the proportion dead of children ever born reported by the women aged 15-19, $d_{15-19}$, is approximately equal to $q(1)$, i.e. the probability of dying by age 1; that reported by women aged 20-24, $d_{20-24}$, likewise approximates $q(2)$, i.e. the probability of dying by age 2; etc.

**Table 4.6:** ***Probabilities of dying by age x corresponding to the age group of mothers.***

| Age Group of Women (*i*) | Reported Proportion Dead of CEB Approximately Equals: |
|---|---|
| 15-19 | $q(1)$ |
| 20-24 | $q(2)$ |
| 25-29 | $q(3)$ |
| 30-34 | $q(5)$ |
| 35-39 | $q(10)$ |
| 40-44 | $q(15)$ |
| 45-49 | $q(20)$ |

These approximate values need to be adjusted because of the effects of the age pattern of childbearing as depicted in equation (4) above. Brass developed a specific set of multipliers or correction factors, $k(i)$, to produce the respective exact values of $q(a')$. These correction factors are based on the mean parities $P_1$, $P_2$ and $P_3$ corresponding to women aged 15-19, 20-24 and 25-29 respectively. The ratios $P_1/P_2$ and $P_2/P_3$ are indices that relate to the timing of the onset of fertility, and consequently the amount of children's exposure to the risk of mortality.

However, different sets of multipliers have emerged over the years based on a range of models of fertility and mortality. Brass's set of multipliers was only to be used in conjunction with the Brass's General Standard life table. Trussell's (1975) modification of the original Brass estimation procedure yielded different sets of coefficients to estimate the multipliers for each of the four different families of model life tables in the Princeton system (United

Nations, 1983). He proposed the following equation to estimate the set of multipliers to be used in correcting the reported proportions dead of children ever born to obtain the respective estimates of $q(x)$, where $x$ takes the range of values of $a'$:

$$k(i) = a(i) + b(i).P_1/P_2 + c(i).\ P_2/P_3 \qquad \text{——} (6)$$

where $a(i)$, $b(i)$ and $c(i)$ are sets of 'Trussell' coefficients, and $P_1/P_2$ and $P_2/P_3$ are, as stated earlier, parity ratios controlling for the effects of the age pattern of childbearing.

The $q(x)$ values obtained can be used to determine the corresponding levels of mortality, $\alpha$, and estimates of under-five mortality, $q(5)$ in Brass' logit relational model. The logit of the complement of each of the estimated values of $q(x)$, $Y(x)$, compares with the adopted Princeton mortality model thus

$$Y(x) = \alpha + \beta.Y_s(x) \qquad \text{——} (7)$$

where $\beta$ is the parameter indicating the age pattern of mortality, and $Y_s(x)$ is the logit of the corresponding $l(x)$ in the mortality model being used as a standard.

One of the assumptions of the technique is a constant pattern of mortality over the period of time being considered — implying $\beta = 1$. As a result, a one-parameter logit relationship is obtained as:

$$Y(x) = \alpha + Y_s(x) \qquad \text{——} (8)$$

$$\Rightarrow \quad \alpha = Y(x) - Y_s(x) \qquad \text{——} (9)$$

From equation (8), it follows that an estimate of $Y(5)$ can be derived from each of the estimates of $Y(x)$ from the relationship

$$Y(5) = \alpha + Y_s(5) \qquad \text{——} (10)$$

where $Y_s(5)$ is the logit of the value of $l_s(5)$ from model standard. Therefore, adding the fixed value of $Y_s(5)$ to each value of $\alpha$ gives the corresponding estimates of $Y(5)$. The anti-logits of these estimates of $Y(5)$ give the corresponding values of $l(5)$, the complements of which — i.e. 1- $l_s(5)$ — give the estimates of $q(5)$ corresponding to each estimate of $q(x)$.

By further assuming a linear decline in mortality, one can estimate the reference periods, $t(x)$ in years prior to the respective enquiries, when the corresponding levels of $q(x)$, $\alpha$ and $q(5)$ prevailed. Trussell (1975) proposed the following reference-time estimation equation:

$$t(x) = a(i) + b(i).P_1/P_2 + c(i).\ P_2/P_3 \qquad \text{—— (11)}$$

where $a(i)$, $b(i)$ and $c(i)$ are the time location coefficients for the mortality model adopted; and $P_1/P_2$ and $P_2/P_3$ — the parity ratios — take into consideration the age pattern of childbearing over the period being considered. Since $t(x)$ represents the period in years prior to the respective enquiries, the reference dates are simply the differences between the survey or census dates and the corresponding estimated time locations.

### *4.4.3 Data Quality*

It is apparent from the description of the technique above that the accuracy and reliability of results obtained through the application of the method will depend on three main issues. These are:

a. the quality of the data relating to children ever born and the proportions dead by age group of mothers. The proportions dead of children ever born represent the fundamental constituents of the technique;

b. the quality of the fertility data relating to average parities of women, which essentially control for the effects of the age pattern of childbearing;

c. the selection of an appropriate mortality model.

In this regard, one can assess the quality of the data available through the application of certain consistency checks. The checks that can be applied based on the available information are:

a. examination of sex ratios of children ever born by age group of mothers, as well as total children ever born;

b. inspection of the proportions dead of children ever born by age of mothers; and

c. examination of the average parities by age of women.

*Sex Ratios of Children Ever Born*

On the basis that about 105 male children are born for every 100 female children given birth to in most populations, examination of the sex ratio at birth constitutes an efficient way of evaluating data relating to children born in a specified period of time in a given population. In this circumstance, however, children are being considered by the age groups of their mothers and therefore may not necessarily have been born at the same periods. The ratios obtained by age group of mothers for every DHS included in the study are presented graphically in Figure 4.2 by sub-region of the continent.

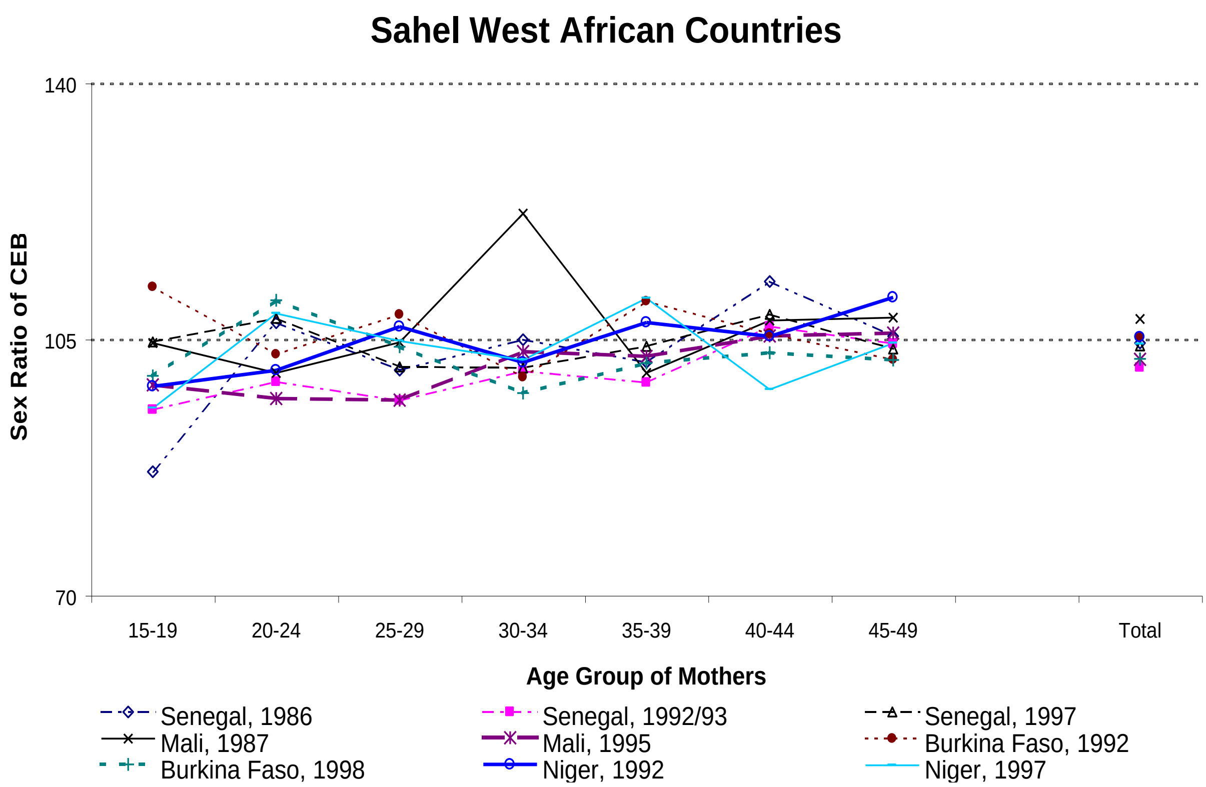
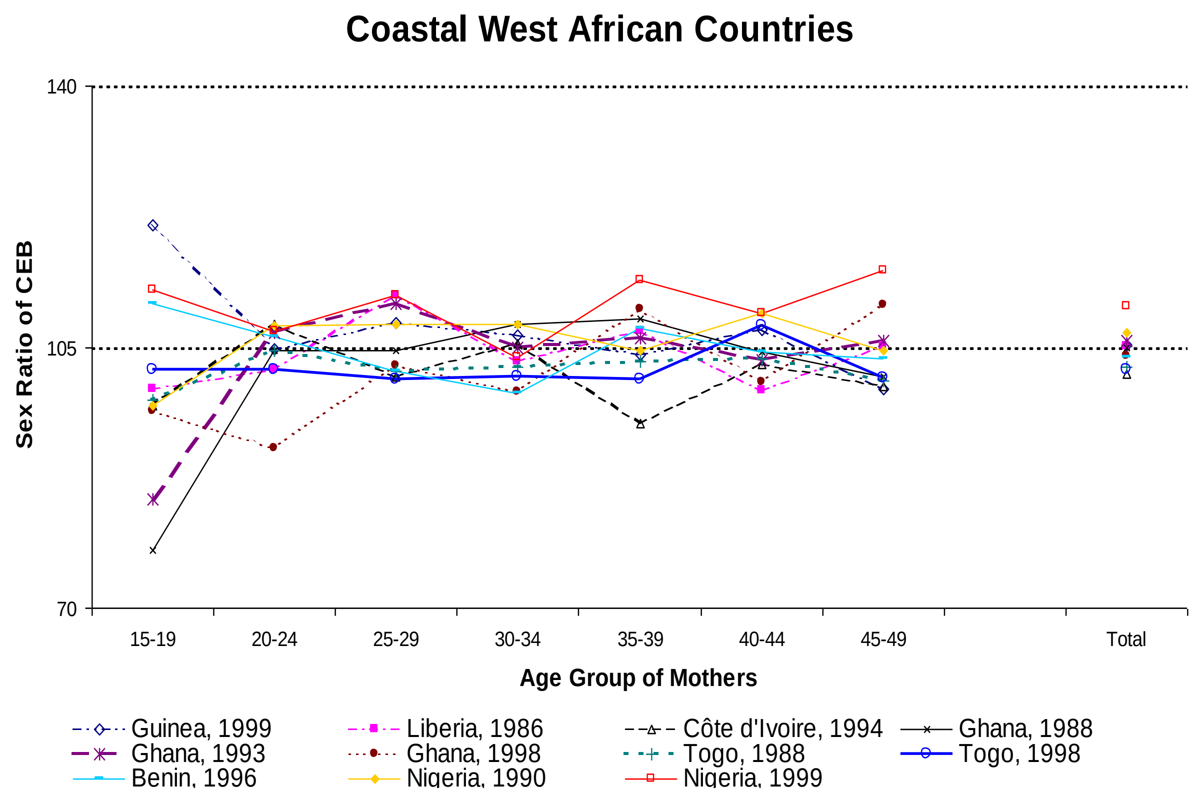



**Figure 4.2**: ***Sex ratios of total children ever born by age group of mothers and country and year of survey***

**Figure 4.2 — *continued*.**



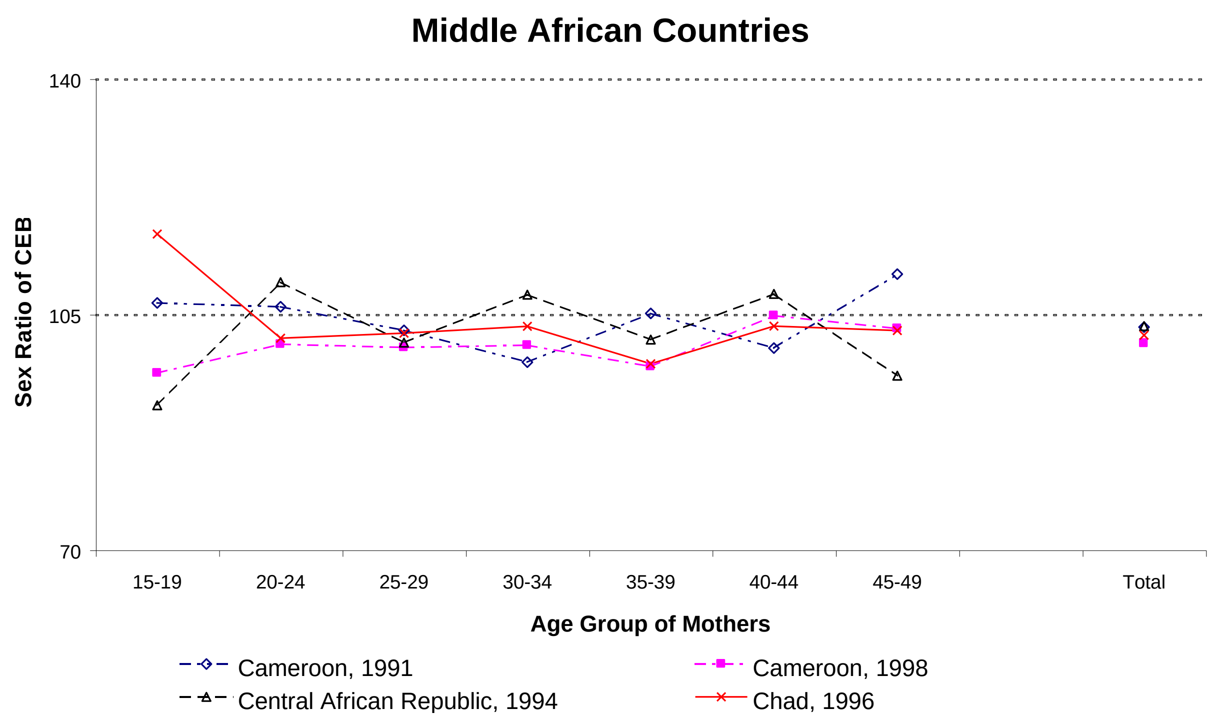
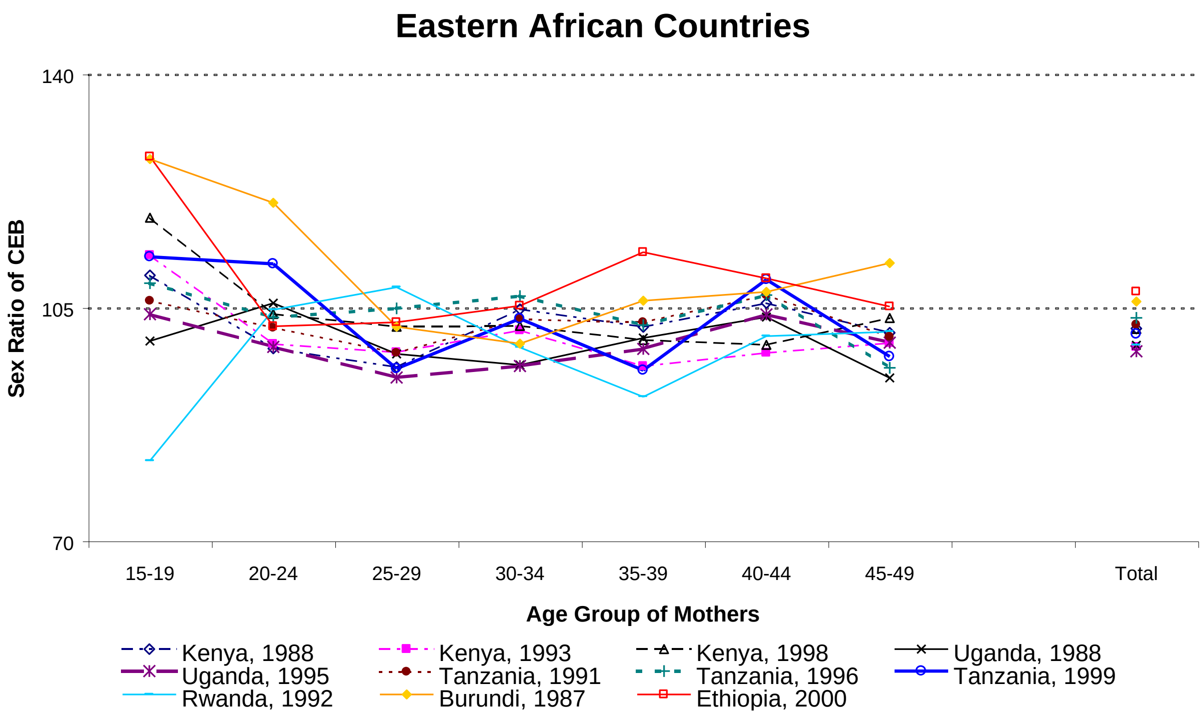
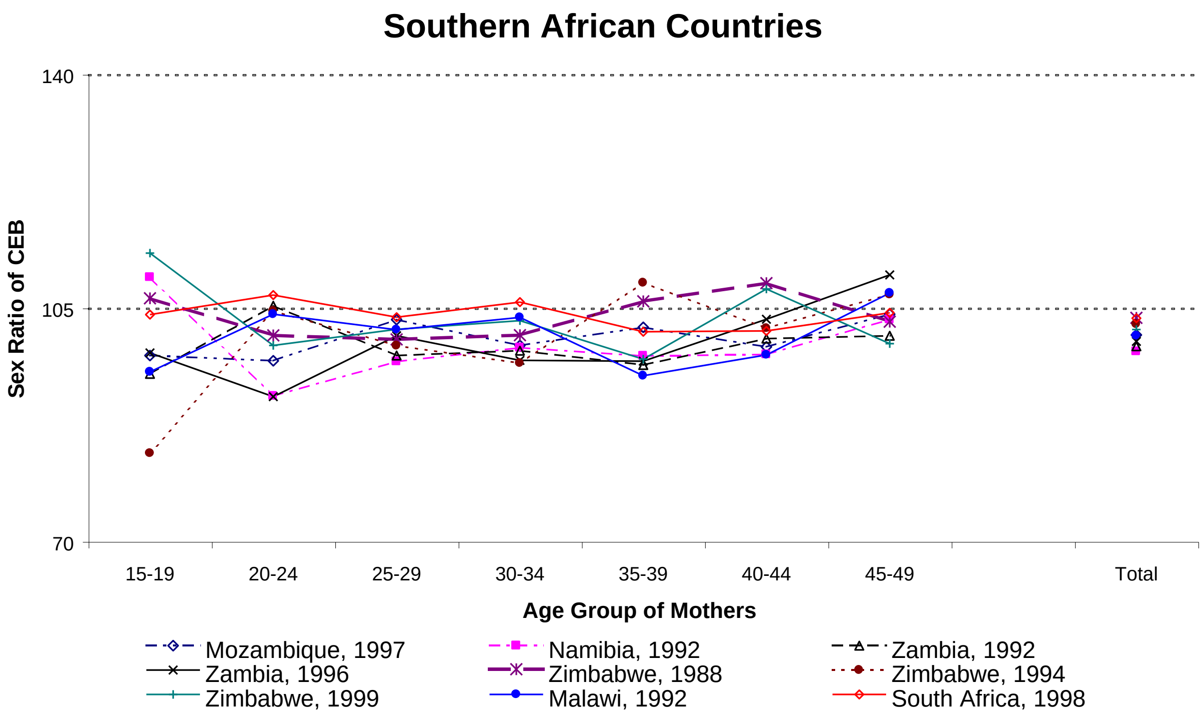



**Figure 4.2 — *continued*.**



One common feature of the ratios obtained from each survey is the fluctuation by age of mother. Apparently, they do not depict any systematic pattern. The main explanation for this is that the surveys constitute samples that are small.

Some of the rather unconventional sex ratios observed among children born to women aged 15-19 may be attributed to this, coupled with the fact that fewer children are born to women of this age group than any other in any population. The sex ratios as low as 78 observed in every part of the continent should not be interpreted as under-reporting of male births, which may not even make sense in a continent largely characterised by patrilineal societal norms and customs. Also, there is no evidence to suggest that mothers aged 30-34 under-reported female births in Mali in 1987 thus warranting the observed sex ratio of over 120 males per 100 females. Generally, though, all other computed sex ratios by age group of mothers appear to be acceptable.

The sex ratios for all the children ever born probably give more meaningful information regarding the quality of the birth histories being used for child mortality estimation. Figure 4.2 shows these ratios to be extremely close to the expected value of 105 for each survey. The highest of 108 was recorded from the 1987 Malian DHS, and the lowest of 98 from the 1992 Namibian DHS. It appears, though, that an average of 103 males per 100 females better describes the situation in all countries considered in the study. With this overall sex ratio, it can be concluded that no obvious deficiency has been detected in any of the data sets on the basis of this test.

*Proportions Dead of Children Ever Born*

The proportions dead of children ever born by age group of mothers are expected to increase with age of mothers. This is because children of older women born further back in the past have longer periods of exposure to the risk of dying than children of younger women. In some instances, however, this rule excludes women aged 15-19 whose children have a greater risk of dying than those born to women aged 20-24. Such proportions were computed from all available data and represented graphically by country in Figure 4.3. Some countries have only one DHS dataset, and as a result not much can be said about the derived proportions dead of children ever born by age group of mothers. However, the results from such single-dataset

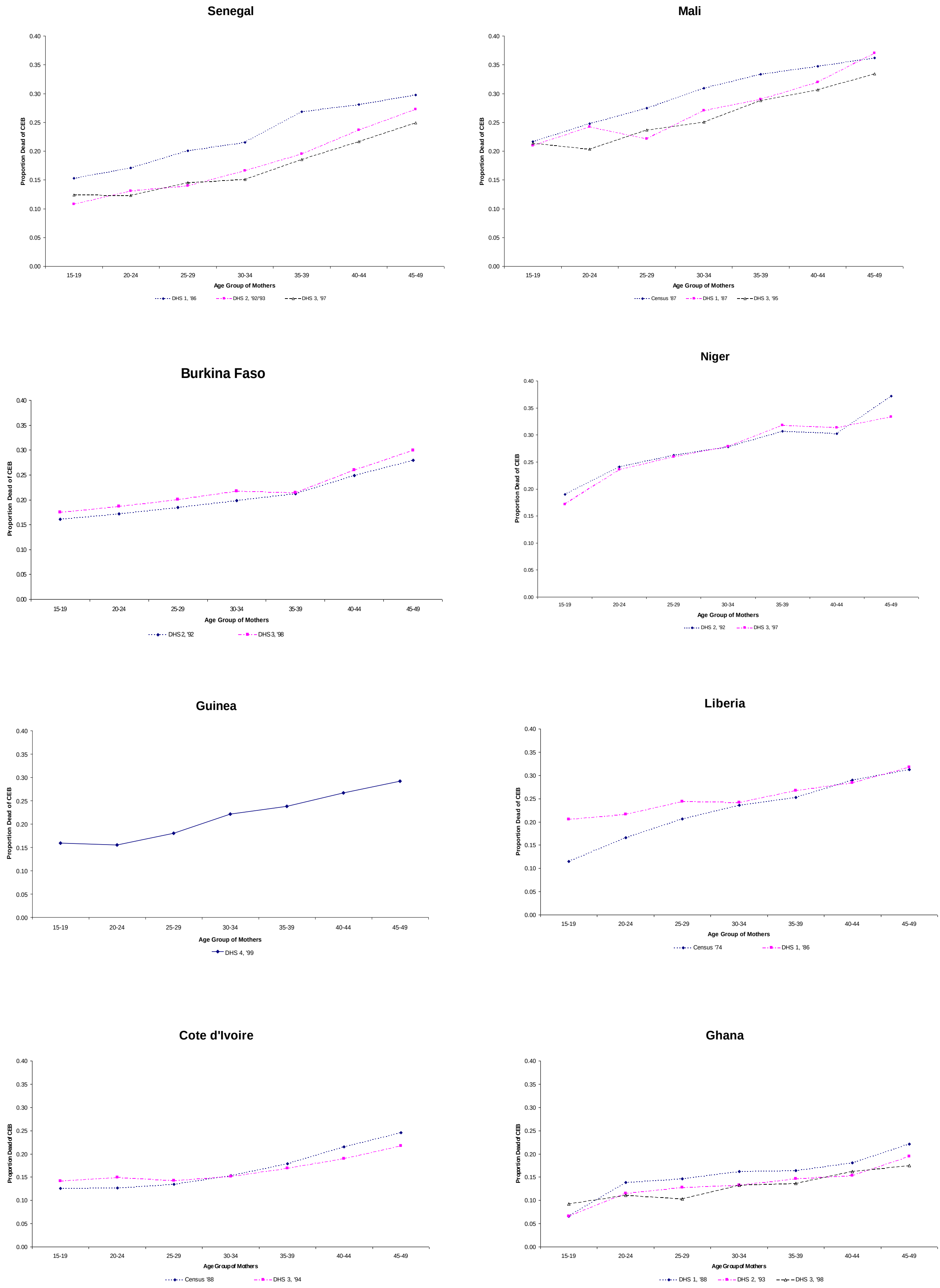
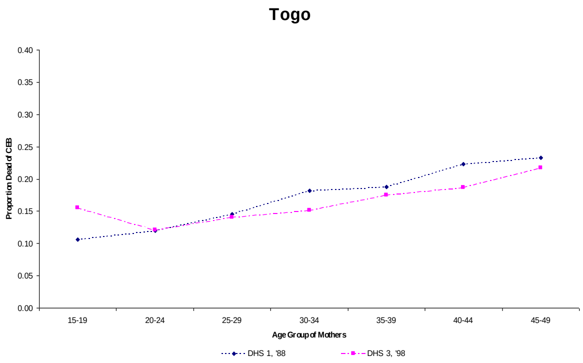
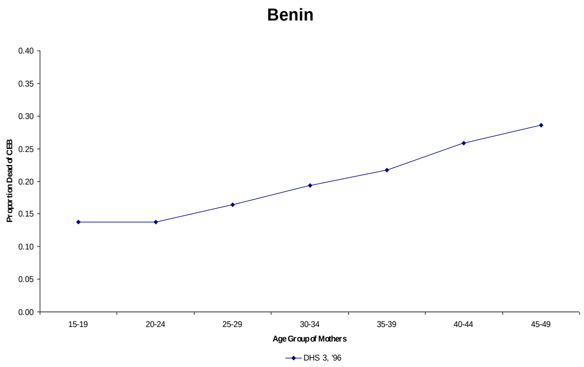
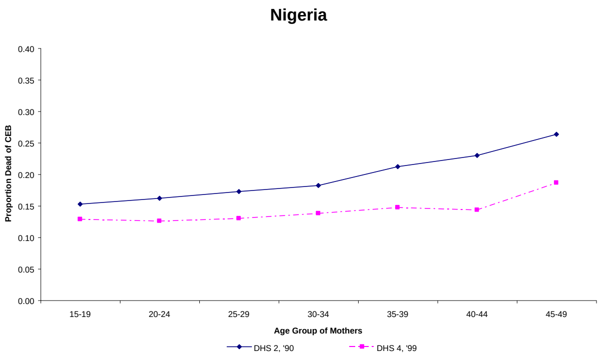


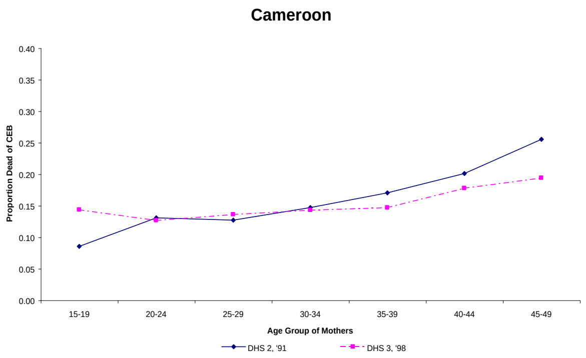

**Figure 4.3**: ***Comparison of proportions dead of children ever born by age of mothers obtained from different sources and periods***.

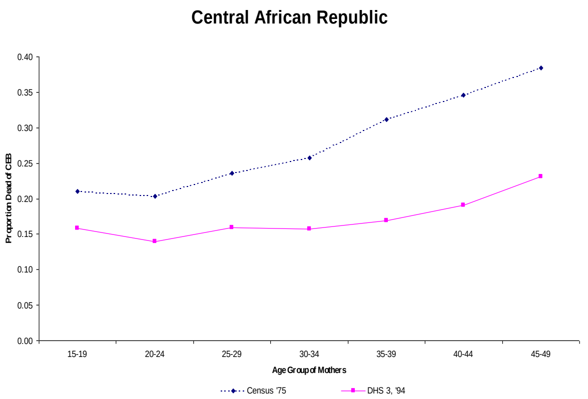
**Figure 4.3 — *continued*.**

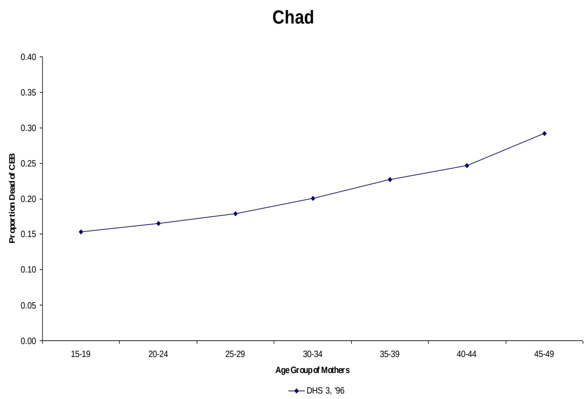


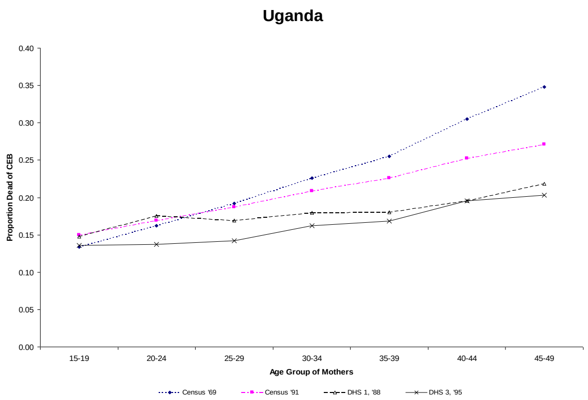



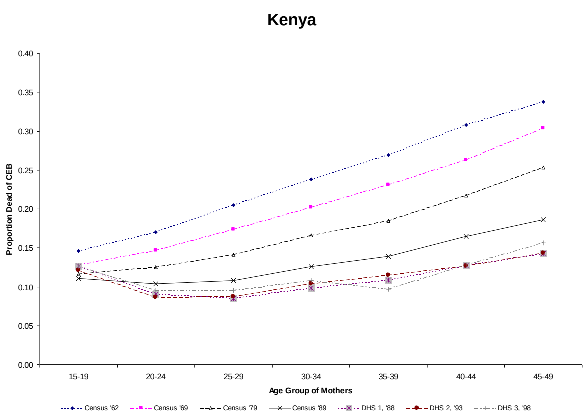
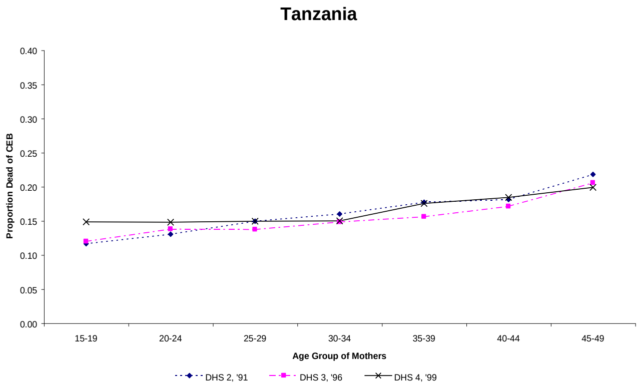
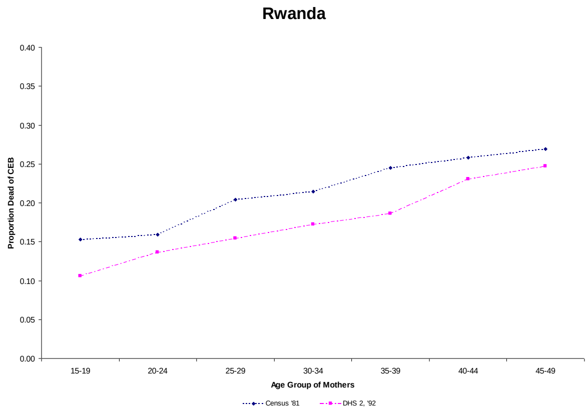
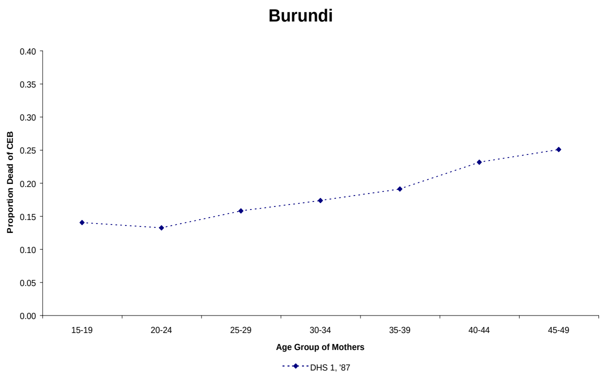
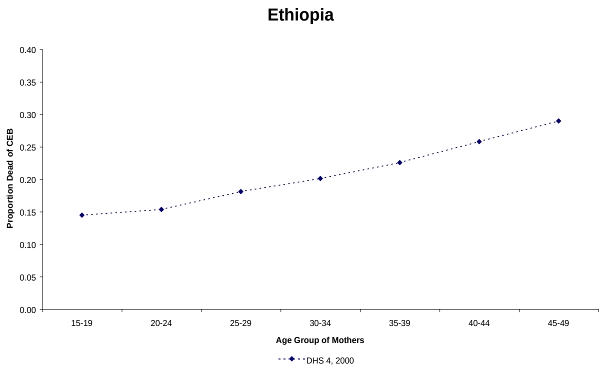



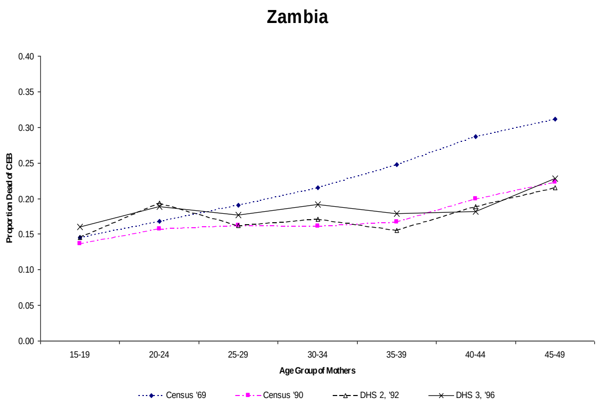
**Figure 4.3 — *continued*.**

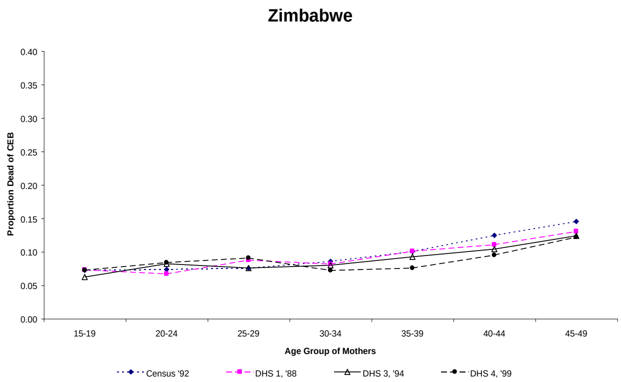


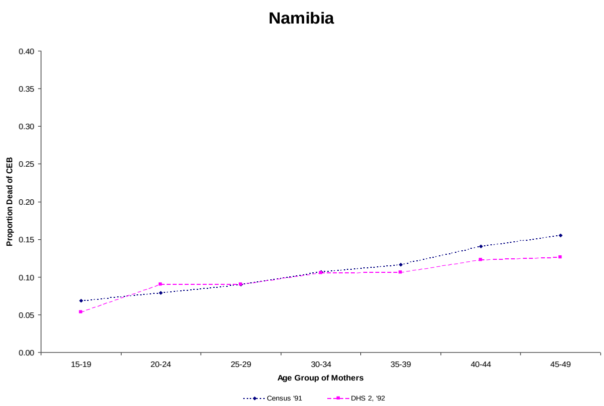



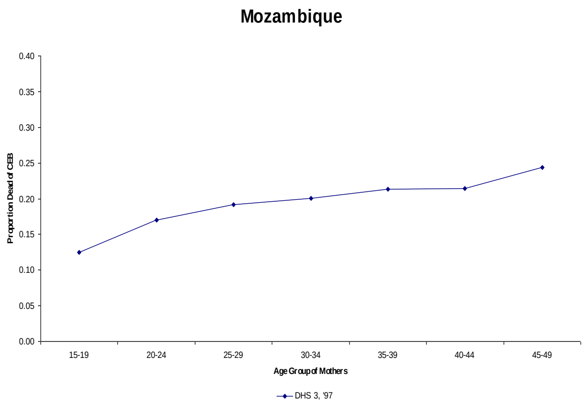



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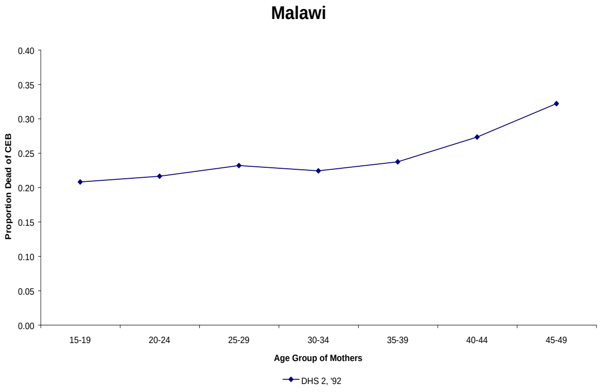
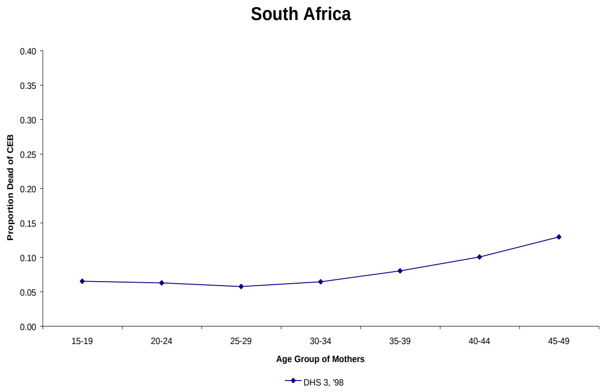



Sources: *National Demographic and Health Surveys and Censuses.*

countries show the expected pattern of increasing proportions by increasing age of mothers, thereby suggesting the likely absence of inconsistencies in those respective data sets. For all other countries with more than one data set, the expected pattern of increasing proportions dead of children ever born by age of mothers was generally observed from all the datasets used except the two DHS data sets from Zambia.

The availability of more than one set of estimates of proportions dead of children ever born obtained from enquiries conducted at different points in time permits assessment of the reliability of each set against those referring to different time periods. As such, indications are obtained as to what the general trend of child mortality has been like between the periods the different data sets refer to.

In Mali, for instance, the census and the DHS conducted in the same year — i.e. 1987 — show significantly different proportions dead of children ever born. The DHS estimates are lower than those obtained from the census, especially for mothers aged 25-44 years. Also, the 1995 DHS — i.e. seven years later — yielded proportions dead of children ever born by age group of mother that are similar to those from the 1987 DHS, implying stagnation of childhood mortality levels in Mali between 1987 and 1995. However, considering the fact that the 1987 census must have had a higher level of coverage than the 1987 DHS — which is a sample by design — it can only be concluded that the 1987 DHS under-estimated the level of childhood mortality, and that the census estimates may be more reliable. The estimates from the 1995 DHS can be regarded as more plausible since they indicate an acceptable drop in childhood mortality levels between 1987 and 1995 when compared with the 1987 census estimates. There is, however, no other source to confirm this. As a result, childhood mortality estimates derived from the 1987 Malian DHS will be interpreted with caution.

Only DHS-type data sources are available for Senegal, Niger, Ghana, Togo and Tanzania. Estimates of proportions dead of children ever born for Senegal and Ghana show quite acceptable patterns, with a clear indication that decline in childhood mortality in both countries was faster between the first and second DHS rounds than between the second and third rounds. There are, however, no indications of inconsistencies in the data sets from either country.

Niger, Togo and Tanzania, on the other hand, show slight differences in the estimated proportions dead of children ever born by age group of mothers between the earlier and the later DHS rounds, implying near stagnation of child mortality levels for a five-year period in Niger and Tanzania, and a decade in Togo (see Figure 4.3). As in Senegal and Ghana, no evident inconsistencies exist in the data from these countries on the basis of this test.

Five other countries had one census data set and one DHS data set available for the test. These are Liberia, Côte d'Ivoire, Central African Republic, Rwanda and Namibia. Proportions obtained for Central African Republic and Rwanda show very reasonable drops in childhood mortality levels over periods of more than a decade. With a time difference of about a year between the census and DHS in Namibia, the similar levels of proportions dead of children ever born — especially to women between the ages 15 and 39 — are reasonable. The drop observed in the case of women aged 40-49, though not at all an indication of inconsistency in the data set, may simply be a manifestation of difference in the representativeness of the two enquiries.

The case of Côte d'Ivoire is somewhat different from that of Namibia. Despite a gap of about six years between the 1988 census and the 1994 DHS, proportions dead of children ever born show an interesting pattern. Estimates from the 1994 DHS are higher than those from the 1988 census in the case of mothers aged 15-29; and lower for mothers aged 35-49 (see Figure 4.3). However, drawing from the experience of neighbouring Ghana, where available data suggest that childhood mortality levels generally dropped between 1988 and 1993, and on the basis that there has not been any incident in the recent past that would have caused an increase in childhood mortality, it can be concluded that the 1988 Ivorian census under-estimated the proportions dead of children ever born by age group of mother, and consequently the level of childhood mortality in Côte d'Ivoire.

Liberia also presents an interesting scenario. The proportions dead of children ever born from the 1974 census and the 1986 DHS both show the normal pattern of increasing proportions with age of women. However, the significant increase in proportions dead of children ever born to women aged 15-29, as indicated by the two sets of estimates, suggests a significant increase in childhood mortality between the two enquiries. Both enquiries were conducted before the civil war and political crisis set in the country towards the end of the 1980s. The probable explanation for this discrepancy on the basis of this test is that the 1974 census under-estimated the proportions dead of children ever born to women age 15-29. However, similarities in proportions for women aged 30-49 tend to suggest similar childhood mortality levels in Liberia for over a decade.

The estimates obtained from two census and two DHS data sets from Uganda show the expected pattern of proportions dead of children ever born. However, the available information shows that childhood mortality must have dropped between 1969 and 1988, then increased between 1988 and 1991, followed by another drop by 1995. Since there is no evidence of inconsistencies in the data sets, the depicted trend in childhood mortality levels cannot be assessed in this way.

Kenya manifested consistent drops in proportions dead of children ever born between the 1969 and 1989 censuses, but proportions indicated by the 1988 DHS are lower than those obtained from the 1989 census. The apparent conclusion in this case is that the Kenyan 1988 DHS under-estimated the proportions dead of children ever born by age of women. As a result, mortality estimates from this data set will be considered with caution. The slightly higher proportions estimated from the 1998 DHS relative to those obtained from the earlier DHS data sets may be regarded as evidence of a recent slight increase in child mortality in Kenya. This will be confirmed in due course.

Zambia, apparently, is the only country whose estimates of proportions dead of children ever born from DHS data sets do not yield a monotonously increasing pattern with increasing age of women. Interestingly also, the 1990 census indicated a pattern similar to that of the 1992 DHS and the 1996 DHS, but at slightly higher levels, implying recent slight increase in childhood mortality in Zambia. The observed pattern of the proportions dead is not extreme enough to warrant discarding the data sets. They may result from recent fluctuations in child mortality levels. The data sets will be subjected to a further test to assess their value for estimation of childhood mortality in Zambia.

*Average Parities*

Under normal circumstances, average parity is expected to increase with age of women. Deviation from such a pattern is an indication of omission of births, especially those relating to dead children. This recall error can be common among older women (notably those nearing the completion of their reproductive lives), and its presence in a dataset results in under-estimation of childhood mortality for periods a decade or more before the survey. Also, in instances where two sets of data are available for a specific population and referring to different time periods, comparison of the respective average parities gives an indication of fertility trends between the two enquiries.

Using all the census and DHS datasets available for the countries included in the study, average parities by age group of women were computed as the ratio of children ever born to women of a particular age group to the total number of women in that age group. The results are represented graphically in Figure 4.4. The expected pattern of average parities was observed, except for the 1969 censuses of Zambia and Uganda, and the 1997 Mozambican DHS. In these cases, the average parities dipped slightly for women aged 40 years and over in Zambia and Uganda, and for women in the last age bracket in Mozambique. Also, the 1974 Liberian census shows lower average parities than the 1986 DHS, thus implying a significant increase in fertility between 1974 and 1986, which seems unlikely. Therefore, the lower reported average parities from the census may be attributable to possible low census coverage during that period.

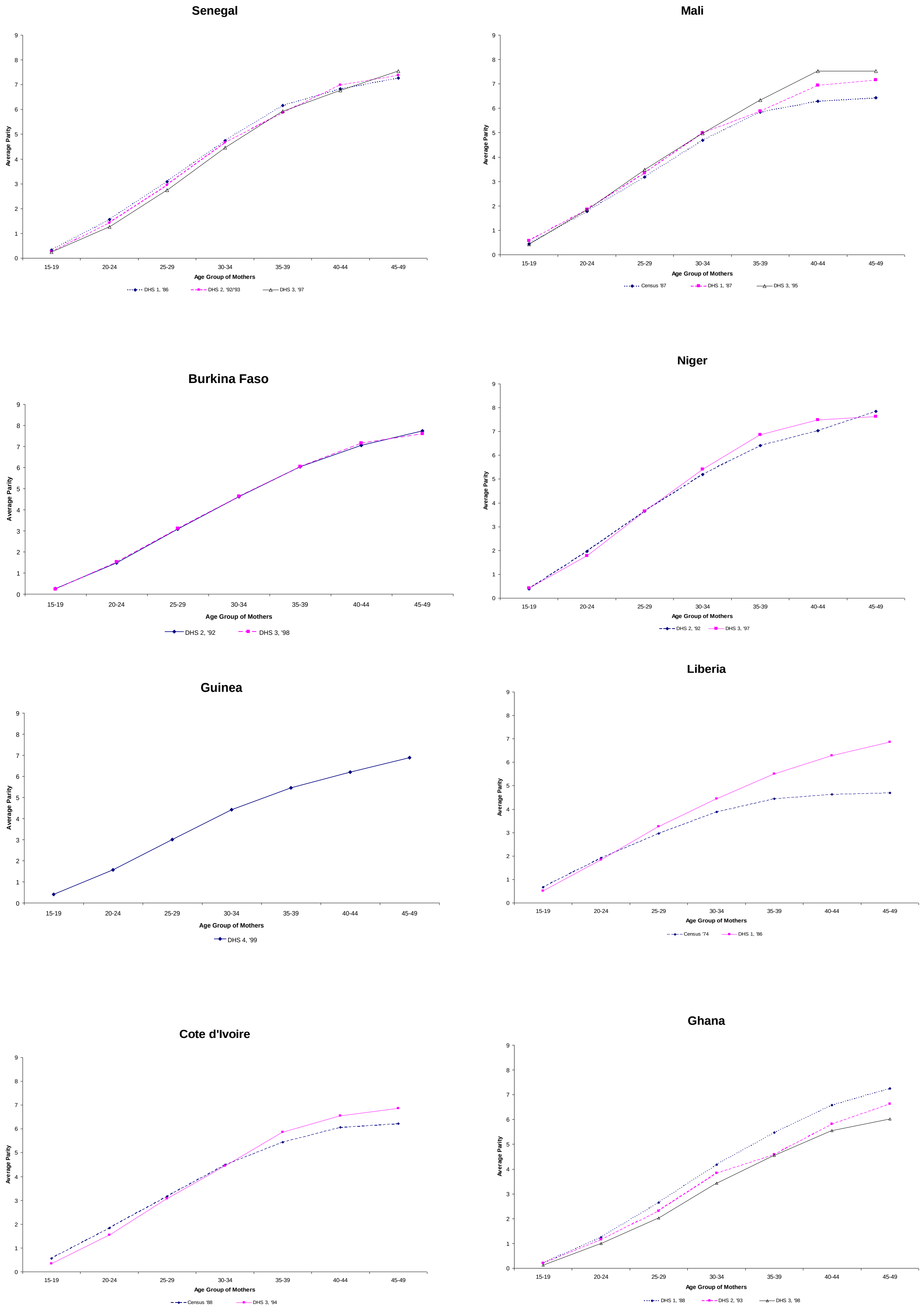
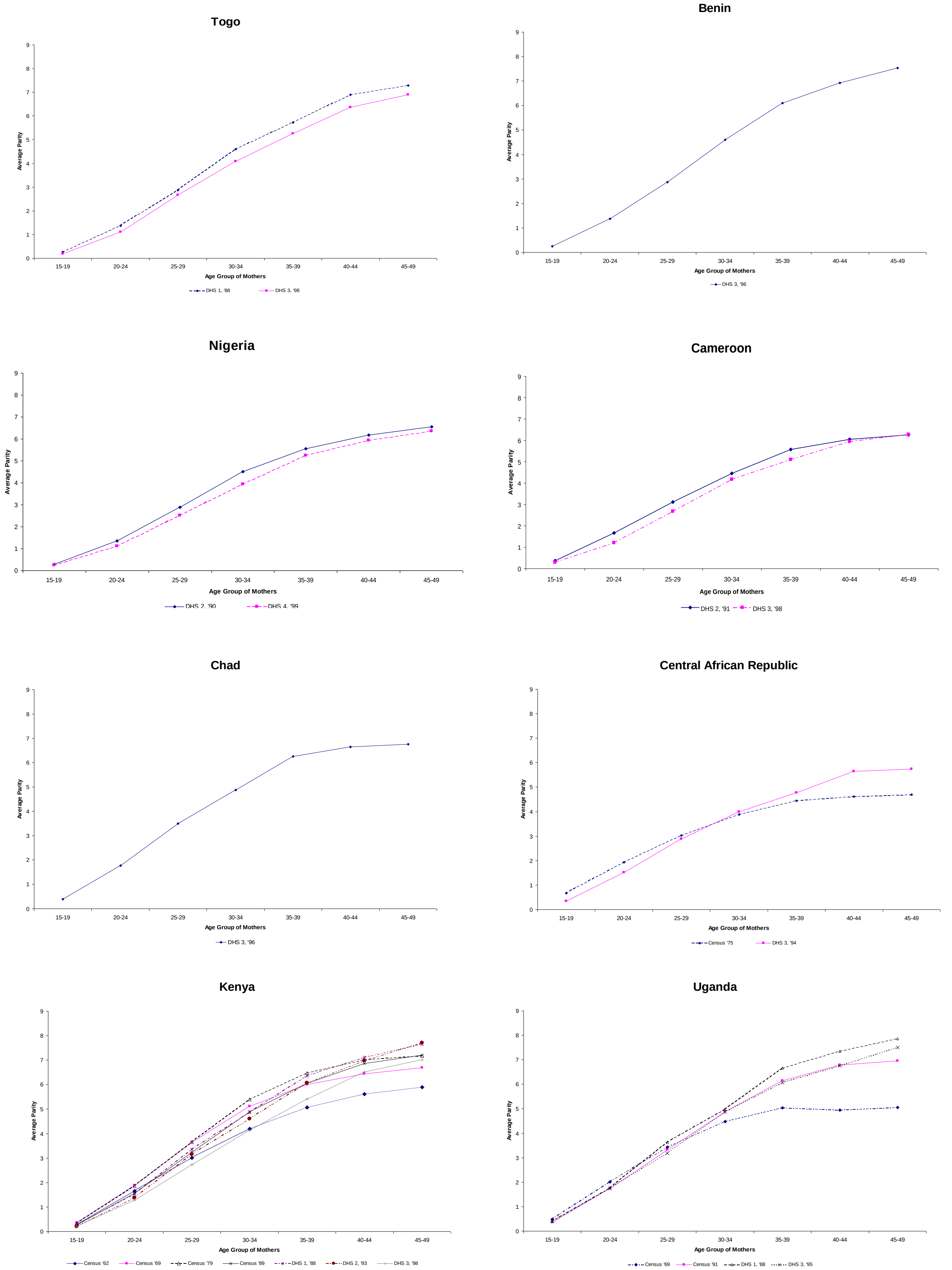



**Figure 4.4:** ***Comparison of national average parities by age of women obtained from different sources and periods.***

## Figure 4.4 — *continued*.



## Figure 4.4 — *continued*.

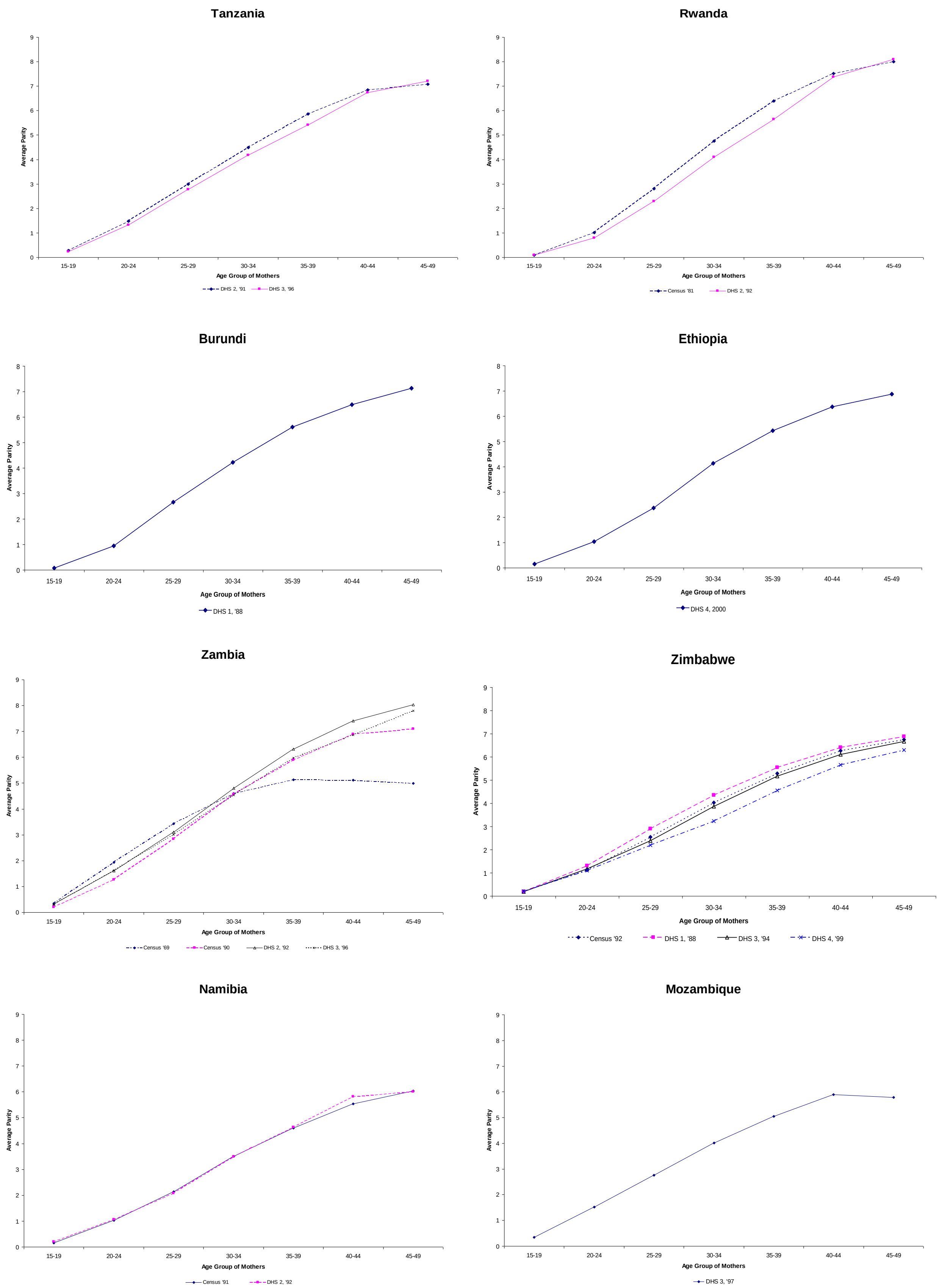
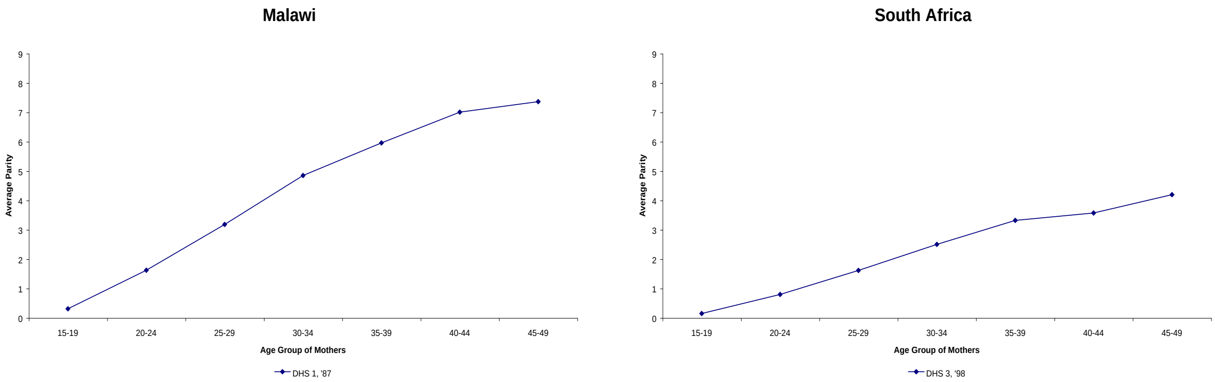


**Figure 4.4 — *continued*.**




Sources: *National Demographic and Health Surveys and Censuses.*

Côte d'Ivoire and Central African Republic also manifest similar scenarios whereby their respective earlier enquiries yielded slightly higher average parities among women aged 15-29 than that obtained from more recent surveys, and the reverse among women aged 30-49. Since in both these cases a census constitutes the earlier enquiry (1975 in Central African Republic and 1988 in Côte d'Ivoire), the anomaly can probably be attributed to low level of census coverage and recall bias among older women. However, misclassification of *"parity not stated"* as cases of zero-parity during an enquiry also has the tendency of introducing such an error, which can be corrected to an extent using the El-Badry technique (described in detail in United Nations, 1983).

Since the DHS-type survey establishes the parity of every respondent, the El-Badry technique could not be applied on the Mozambican 1997 DHS data set. However, application of the technique on the 1987 Malian census, the 1975 Centrafricaine census and the 1990 Zambian census yielded no significant changes to the respective original data.

### *4.4.4 Selection of Appropriate Mortality Model*

The most appropriate mortality model to select for indirect estimation of childhood mortality is usually not an obvious decision to make. It may even be necessary in some situations to make a trial of all four different life table models of the Princeton system to determine which one best represents the mortality pattern of the population being studied. Although all mortality patterns in Africa south of the Sahara are unlikely to be similar (Ekanem and Som, 1984; Blacker *et al*., 1985), the “North” family of the Princeton model mortality patterns has been considered the most appropriate for national populations in the continent and is, therefore, the most extensively used model. However, the decision of which model to use in this study was based entirely on the preliminary indications of the of the relationship between the direct estimates of ${}_1q_0$ and ${}_4q_1$ — infant and child mortality, respectively — obtained from the respective national DHS data sets, superimposed on the similar relations defined by the four families of the Princeton model life table system as shown in Figure 3.5 in the previous chapter.

Using a graphical representation of the recent sets of ${}_1q_0$ and ${}_4q_1$ estimates from each data set presented in Tables 4.1 – 4.5, the model pattern that best describes the infant-to-child mortality relationship is adopted as the most appropriate mortality model for that specific country. The models eventually selected for each of the countries included in the study are as presented in Table 4.7. The results confirm the appropriateness of the North model. Also, only the North and West families are observed to be appropriate for any of the national populations considered in the study.

**Table 4.7:** ***Countries by Princeton mortality models selected for indirect estimation of under-five mortality.***

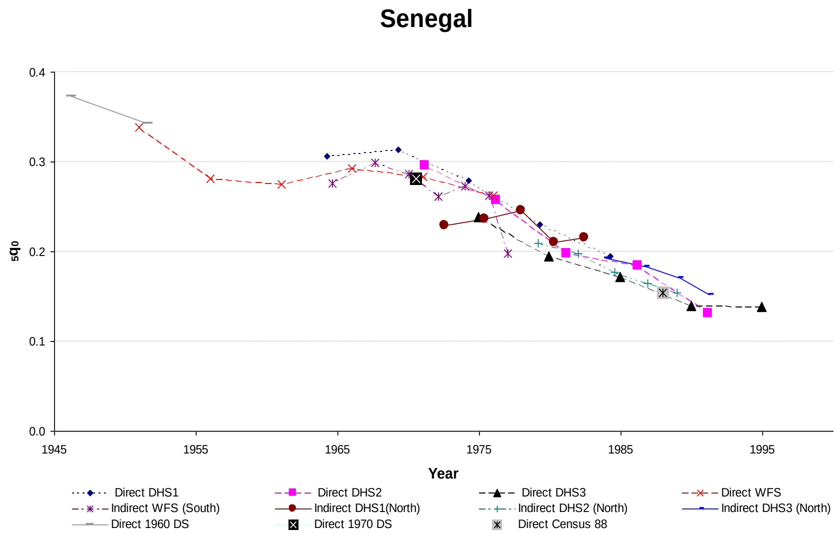
| **North Model** | | **West Model** | |
|---|---|---|---|
| Senegal | Central African Rep. | Liberia | Tanzania |
| Mali | Cameroon | Kenya | Mozambique |
| Burkina Faso | Uganda | South Africa | |
| Niger | Rwanda | | |
| Guinea | Burundi | | |
| Côte d’Ivoire | Ethiopia | | |
| Ghana | Zambia | | |
| Togo | Malawi | | |
| Benin | Zimbabwe | | |
| Nigeria | Namibia | | |
| Chad | | | |

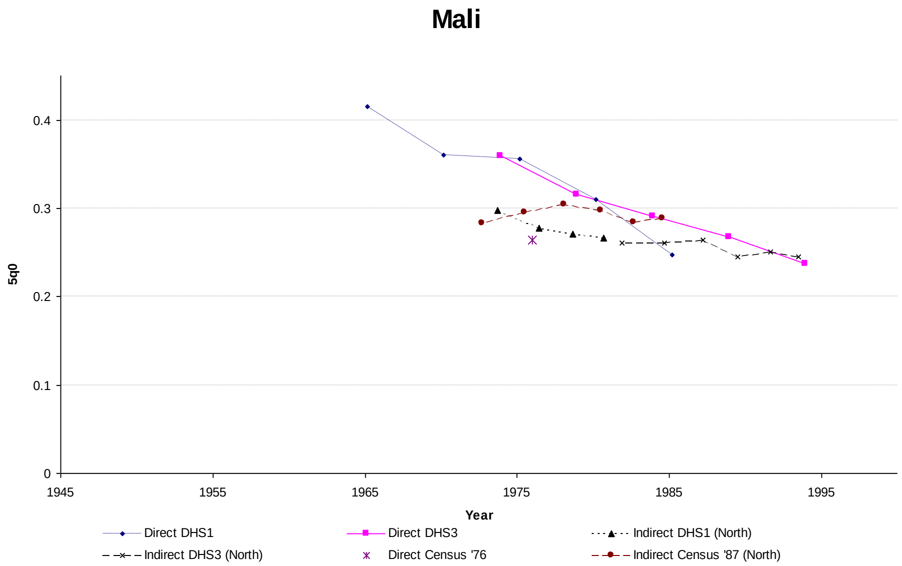
In the case of censuses and other national sample surveys for which direct child mortality estimates are not available to guide model selection, the model adopted for the country on the basis of the DHS data is used, irrespective of the time difference between the enquiries concerned.

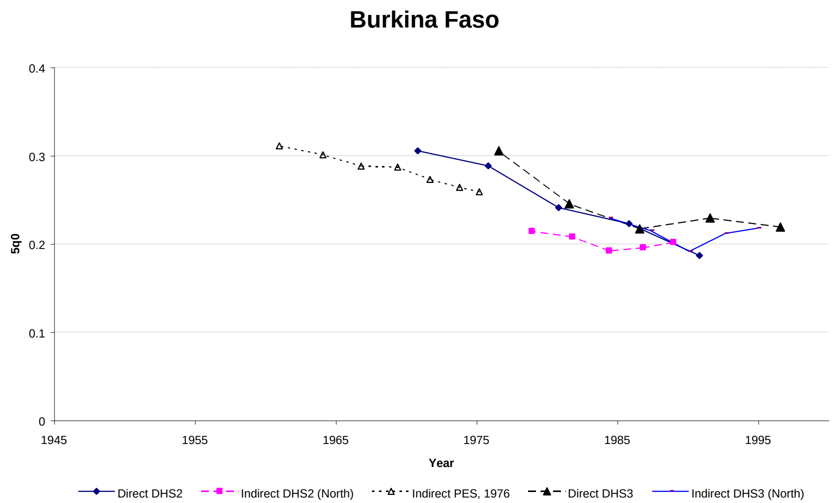
## 4.5 Comparison of Estimates from Different Sources

The assessment of the quality of the respective national DHS data sets is conducted in two stages depending on whether at least one other source of childhood mortality estimates is available. First, directly and indirectly derived estimates from each DHS data set are compared to determine whether they depict similar levels and trends for the fifteen-year period before the survey. The significance of this period rests on the fact that the directly obtained estimates that refer to periods beyond fifteen years before the survey are less reliable because of recall bias; and that the indirect technique yields estimates that span the period three to fifteen years prior to the survey date. Since both sets of estimates come from the same data set, one would expect them to portray more or less the same levels and trends in under-five mortality. In the second stage of the quality assessment, childhood mortality estimates obtained from the DHS datasets concerned — directly or indirectly derived — are subjected to a further test by comparing them with direct and/or indirect estimates from other sources, i.e. censuses and other national surveys including DHS conducted at a different time period. Where the different sets of estimates overlap in time, manifestations of consistent levels and trends to add to the credibility of the DHS data set.

Each of the countries has at least two sets of childhood mortality estimates — i.e. one set of direct and another of indirect estimates. The more sources available to derive estimates directly or indirectly for a particular country, the greater the chances of confirming and validating them or otherwise. Guinea, Chad, Burundi, Ethiopia and South Africa are the only countries with just two sets of estimates from a single DHS dataset, whilst Senegal, Ghana, Kenya, Rwanda, Zambia, Zimbabwe and Malawi have at least seven sets of estimates. The remaining countries are presented with between three and six sets of estimates of under-five mortality. None of these come from sources other than DHS-type data in the cases of Niger and Tanzania. The comparisons of estimates from various sources for each country are presented graphically in Figure 4.5.



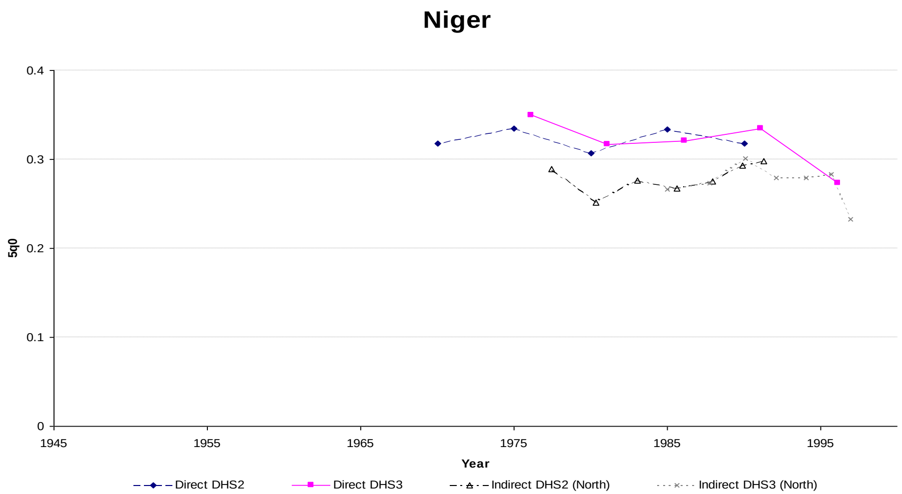




**Figure 4.5**: ***Comparison of directly estimated national levels of $_5q_0$ from DHS birth histories with indirect estimates from proportions dead of children ever born by age of mothers and estimates from other independent sources.***

**Figure 4.5 — *Continued.***

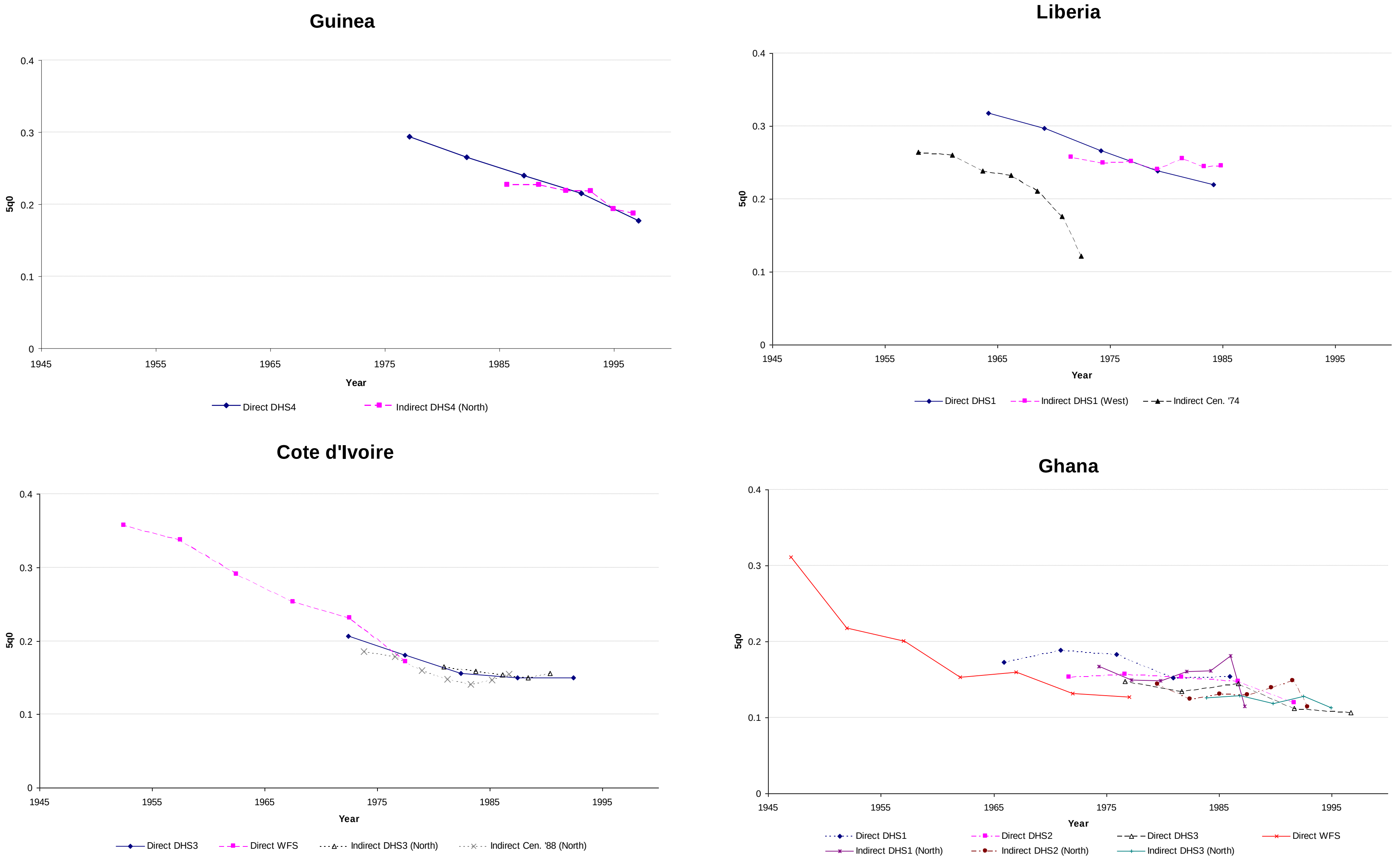


**Figure 4.5 — *Continued.***

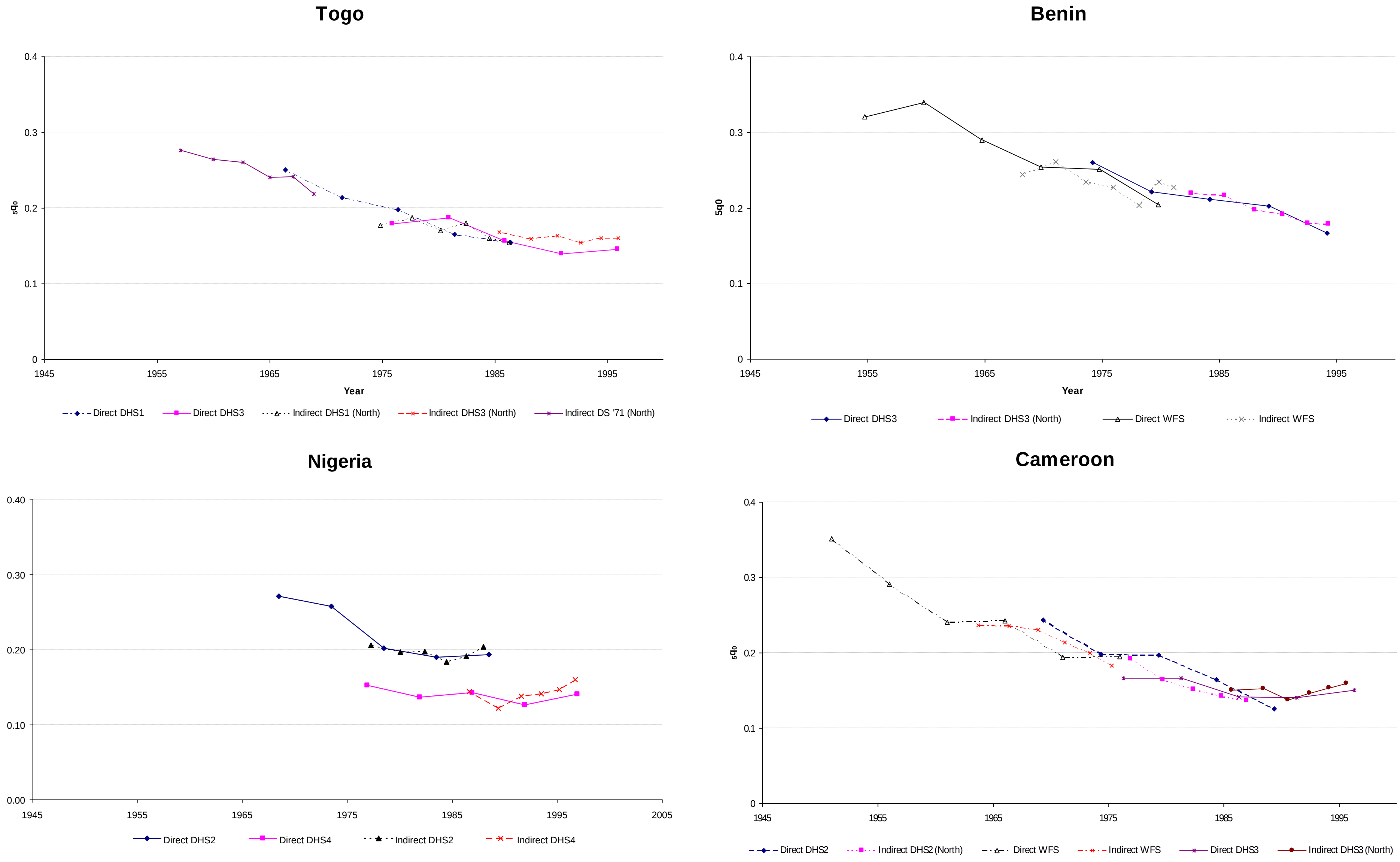
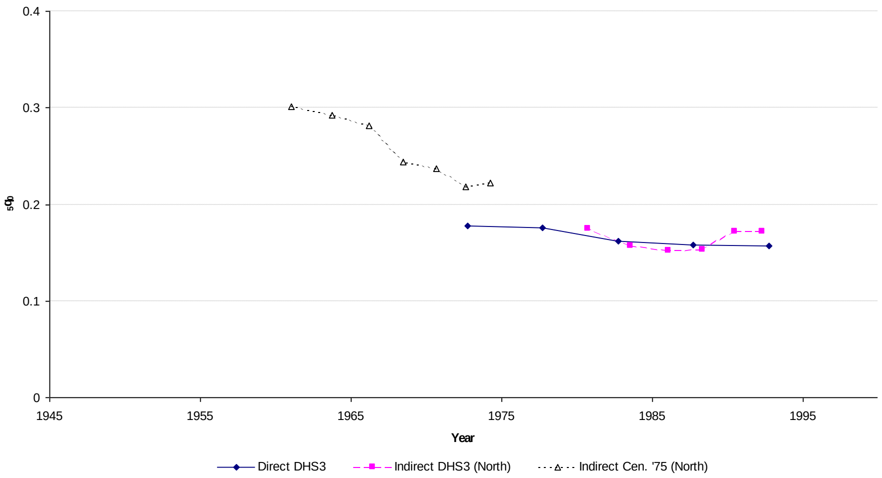
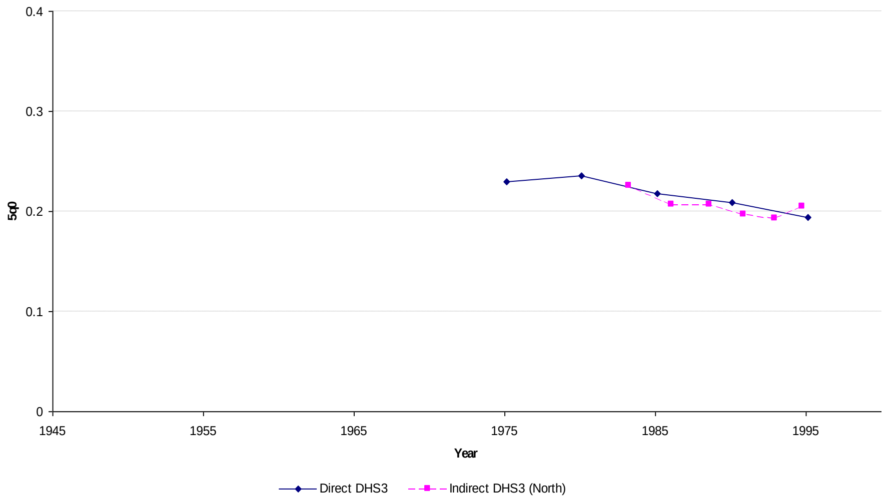


**Figure 4.5 — *Continued.***

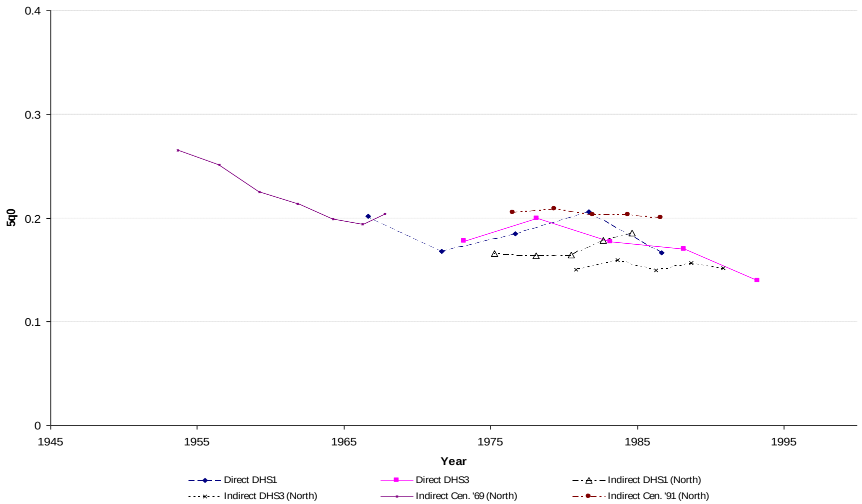
## Central African Republic




## Chad




## Uganda




## Kenya

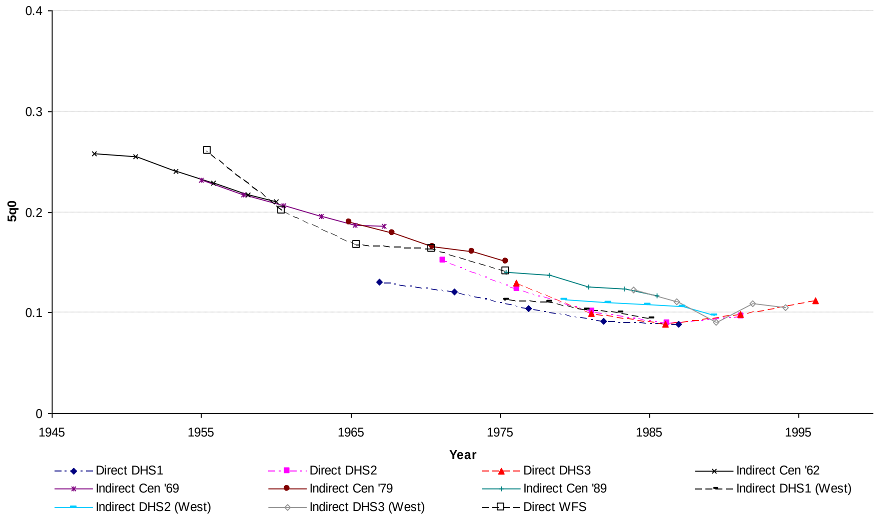
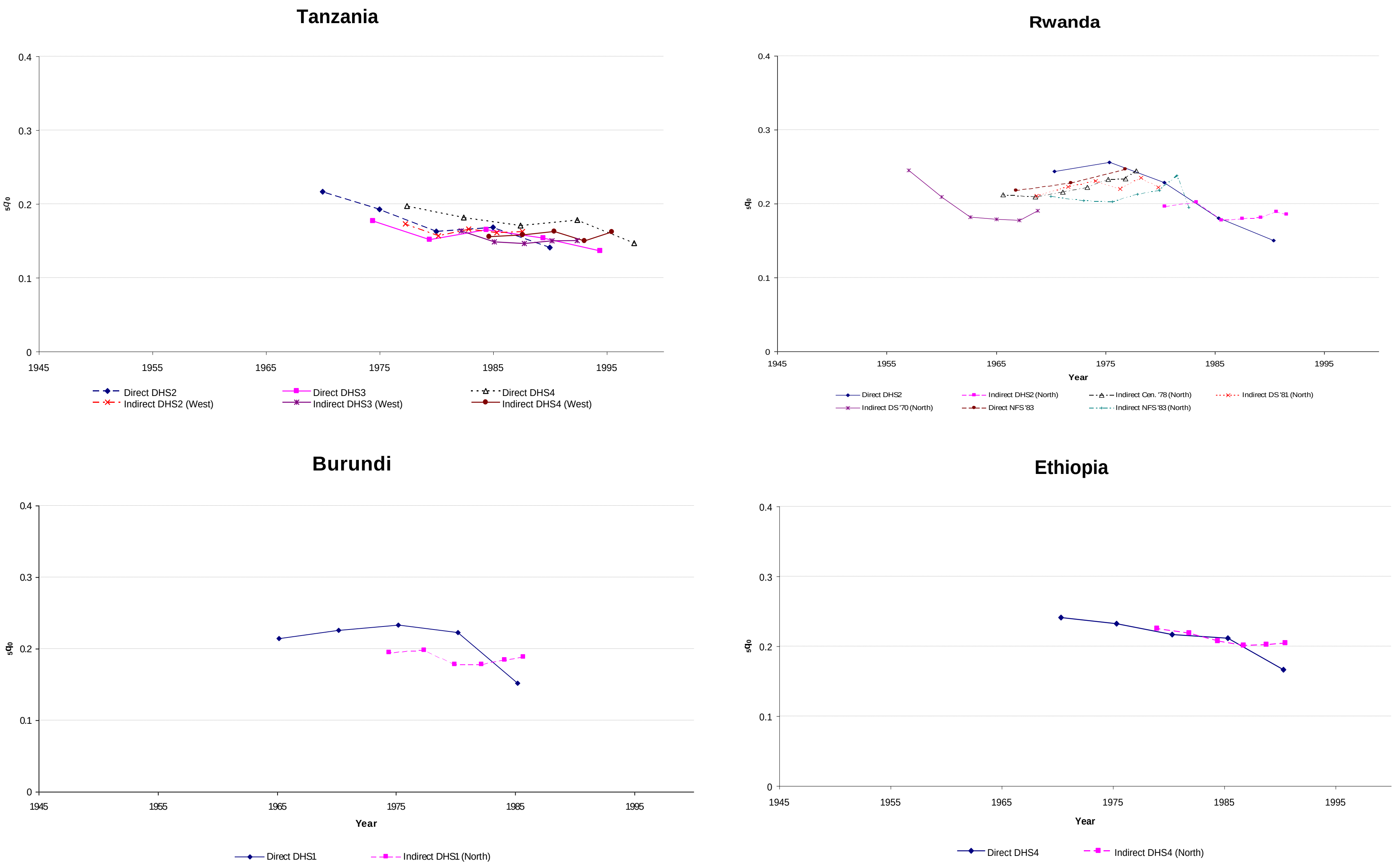


**Figure 4.5 — *Continued.***



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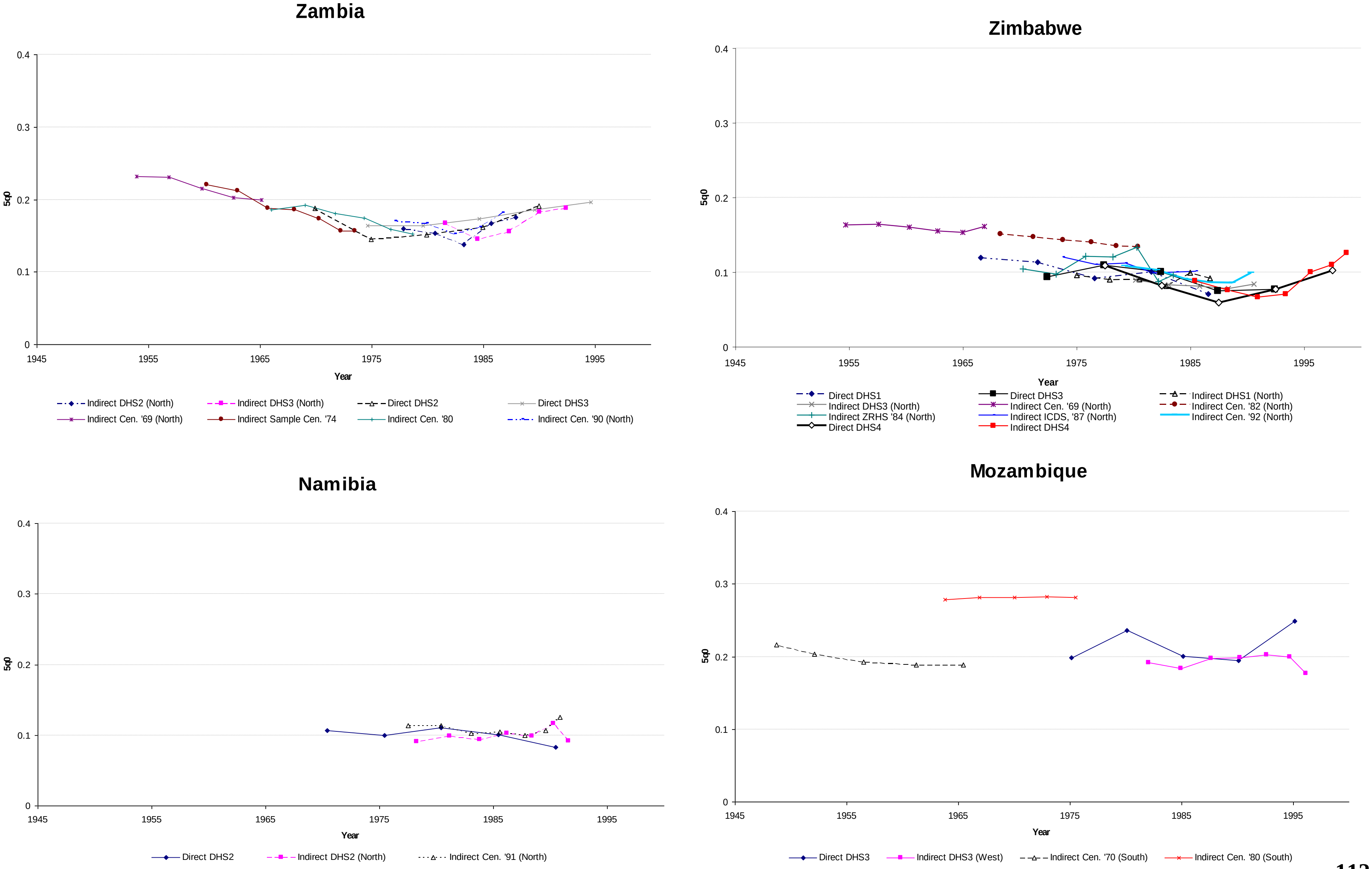

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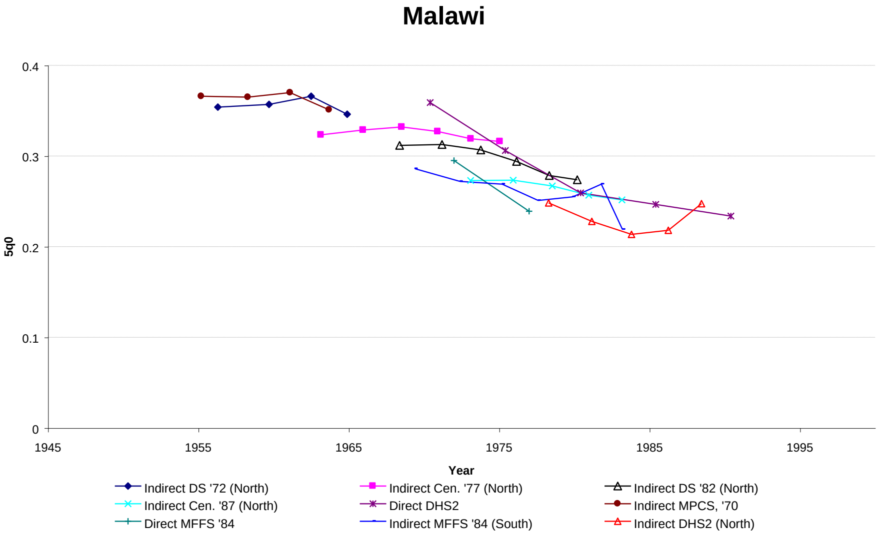
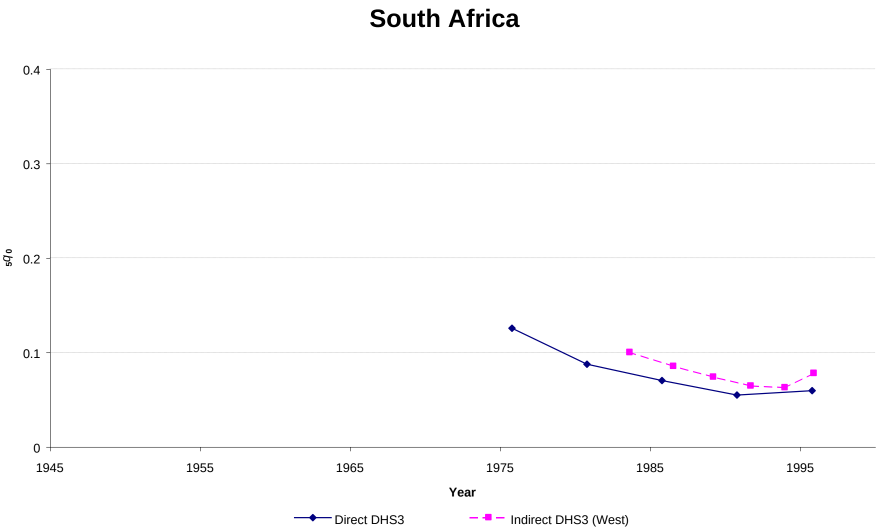



Regarding direct and indirect estimates of under-five mortality from the same DHS data set, twelve surveys from eleven countries produced perfectly matching sets of estimates. The differently derived sets of estimates therefore confirm and validate the levels and trends in childhood mortality they imply. These surveys are the Senegalese first and second phase surveys; the first phase surveys of Togo, Nigeria and Kenya; the second phase survey of Tanzania; the third phase survey of Cameroon; and the only surveys of Guinea, Côte d'Ivoire, Benin, Chad and Central African Republic (see the respective graphs in Figure 4.5).

Fair agreement between direct estimates and Brass-type estimates from the same data set is observed for an additional ten DHS data sets, viz.: the first phase survey of Zimbabwe, those of Zambia and Namibia in the second phase, the third round surveys of Mali, Ghana, Kenya, Tanzania and South Africa, and fourth phase surveys of Nigeria and Ethiopia. With the exception of the Zimbabwean first phase survey, only estimates for the most recent periods of up to about seven years prior to the survey match reasonably well in these cases. Those that relate to earlier dates tend to diverge, with direct estimates being slightly higher than the indirect estimates except in the Kenyan third survey.

Comparison of direct estimates of under-five mortality from the respective DHS data sets with estimates derived from other sources was conducted for each country. Of the Sahel West African countries, Senegal — with eleven sets of under-five mortality estimates — is the only country in the region that demonstrates a high degree of consistency in terms of levels and trends that the different sets portray (see Figure 4.5). Variations between DHS and non-DHS based estimates are insignificant, thus implying that the DHS data sets probably depict the true mortality situation of the country. However, while the first and second round surveys produced direct estimates that agree with each other, the third round survey appears to have under-estimated child mortality slightly for periods beyond fifteen years prior to the survey. Notwithstanding this, the three Senegalese DHS data sets have demonstrated their reliability for use in more detailed assessment of childhood mortality in the country.

DHS-based indirect estimates for Mali, Burkina Faso and Niger are consistently lower than the corresponding direct estimates. Mali and Niger, with two DHS data sets each, further reveal that, while directly derived estimates match each other between the different surveys, the corresponding indirectly obtained estimates also agree with each other. However, Figure 4.3 shows that proportions dead of children ever born derived from the Malian 1987 DHS are significantly lower than those obtained from the census of the same year. Thus it is apparent that the indirect estimates based on this particular DHS under-estimate the level of childhood mortality. Since those obtained from the census and with reference times ranging between 1977 and 1985 seem to be consistent with the direct DHS-based estimates, the trend depicted by the direct estimates appears plausible. In the absence of an independent non-DHS source of estimates for Niger and drawing from the observed tendency for indirect DHS-based estimates to under-state the level of mortality, Niger's two DHS data sets can be accepted tentatively as portraying the true mortality situation of the country within the specified time periods. Due to the low coverage that characterised earlier African censuses and surveys, the indirect estimates from the 1976 Post Enumeration Survey of Burkina Faso may have under-estimated childhood mortality, hence the slight difference in levels with the direct DHS-based estimates where they overlap in time. The direct estimates may represent the real trend of Burkinabe under-five mortality.

The Coastal West African countries, unlike those of the Sahel with the exception of Senegal, present situations in which DHS and non-DHS under-five mortality estimates verify each other by depicting reasonably consistent trends. In Liberia, however, indirect estimates from the 1974 census suggested much lower levels of childhood mortality than the DHS-based estimates. Considering the fact that early African censuses were characterised by low coverage, and recalling that an earlier examination of the proportions dead of children ever born based on this census gave strong indications of under-estimation of childhood mortality (refer to Figure 4.3), it can be concluded that the Liberian DHS-based estimates are more reliable.

Estimates from World Fertility Survey (WFS) data and indirect estimates from the 1988 Ivorian census confirm the accuracy of the childhood mortality estimates derived from the DHS data sets of Côte d'Ivoire and Benin. Earlier examination of proportions dead of children ever born predicted the slightly lower levels of mortality indicated by the indirect estimates from the 1988 Ivorian census. Togo's first and third round DHS data sets jointly manifest an extremely good fit in the form of a consistent and feasible trend. This trend is further confirmed and strengthened by indirect estimates from the country's 1971 National Demographic Survey. Six sets of under-five mortality estimates and one set from WFS data also attempt to represent Ghana's childhood mortality experience. Despite the slight variations between the levels of different set of estimates, a clear trend is manifest. There is no obvious reason, therefore, to suggest that any of the eight national DHS data sets from the five Coastal West African countries included in this study are unsuitable for analysis of age patterns of mortality in childhood.

All three countries in the Middle African region have collected one DHS data set, together with one census, in the case of Central African Republic, and a set of WFS data for Cameroon. In Cameroon, the DHS-based estimates are reasonably matched by those from the

WFS data. In the case of Central African Republic, internal checks on the 1975 census conducted earlier did not reveal any inconsistency in the data. The indirect estimates of under-five mortality obtained from this census can therefore be taken to represent the earlier trend of childhood mortality in the country. With the direct and indirect DHS-based estimates clearly matching each other for the decade and a half prior to the survey, it can be concluded that the direct estimates with reference times beyond the 15-year period before the survey under-estimate childhood mortality in the country. This, however, does not render the country's DHS data set unsuitable for in-depth childhood mortality analysis. The direct and indirect estimates from Chad's only DHS data set depict similar levels and trends in childhood mortality.

In the Eastern region, Kenya's eleven sets of estimates — six of which are DHS-based — depict a consistent trend despite the apparent slight variations between different sets of estimates. As hinted earlier based on the proportions dead of children ever born, the first round DHS under-estimates childhood mortality in Kenya. In the absence of data sources other than DHS, the second and third round Tanzanian surveys agree well in terms of childhood mortality levels and trends. In the case of Uganda, there is a good fit between latest indirect estimate from the 1969 Census and the earliest direct estimate of the 1988 DHS. However, there exist significant variations between the DHS-based direct and indirect estimates. The indirect estimates have consistently been lower than the direct estimates. If the direct estimates are anything to go by, the depicted trend is one of declining childhood mortality up to the early 1970s, followed by a slight increase before a gradual decline eventually sets in at around the early 1980s. Some of the estimates from the 1991 census reflect the same level of childhood mortality around that period (see Figure 4.5).

Although low estimates referring to remote periods in the past relative to more recent estimates are usually associated with recall bias, and hence under-estimation of childhood mortality, the case of Rwanda appears to suggest otherwise. Estimates from three independent enquiries seem to verify the increase in childhood mortality that the earliest two DHS-based direct estimates depict between 1970 and 1975, although at slightly lower levels. These estimates are those directly derived from the 1983 Rwandan National Fertility Survey (NFS), and those indirectly obtained from the 1981 Demographic Survey and the 1978 census (see Figure 4.5). The indirect estimates from the 1983 NFS data seem to have under-estimated childhood mortality. From around 1985, no estimates from independent sources are available to confirm either of the two scenarios the DHS-based indirect and direct estimates depict. Notwithstanding this, the Rwandan second phase DHS data set is a justifiably appropriate data source for further analysis of childhood mortality.

Zambia and Zimbabwe have at least eight sets of under-five mortality estimates, four of which are DHS-based. Mozambique and Namibia have four and three set of estimates respectively, with two being DHS-based in each case. Whereas the indirect estimates from the 1970 Mozambican census appear to portray similar childhood mortality levels to the DHS — i.e. about 200 per 1,000 — estimates from the 1980 census that cover the time gap between the other two sets suggests a rather stagnant, but significantly higher level, of childhood mortality. Neither of the Mozambican censuses can therefore corroborate the fairly reasonable fit between the direct and indirect estimates from the DHS data set. The Namibian 1991 census, on the other hand, satisfactorily corroborates the DHS-based estimates of under-five mortality between around 1980 and 1992 by indicating a consistent trend.

Direct estimates from both Zambian DHS data sets are closely matched by the indirect estimates from the 1980 and 1990 censuses, although estimates for earlier periods from the second phase DHS appear to have slightly under-estimated childhood mortality. Despite the fact that the indirect estimates from the third round survey data set indicate lower childhood mortality levels than the corresponding direct estimates, all set of DHS-based and non-DHS based estimates of under-five mortality in Zambia consistently depict the same trend.

In Zimbabwe, the relatively lower estimates of proportions dead of children ever born obtained from the Zimbabwean first round DHS relative to those from the 1992 census shown in Figure 4.3 confirm that childhood mortality is under-estimated by the 1988 DHS. However, the indirect estimates obtained from the 1987 ICDS and the 1992 census jointly corroborate estimates from the third round survey. Apparently, mortality levels in childhood were over-estimated by the 1969 and 1982 censuses; whereas estimates derived from the 1984 Zimbabwean Reproductive Health Survey do not depict a trend consistent with those of the other estimates.

With the exception of the first round DHS data sets from Kenya and Zimbabwe, which clearly under-estimated under-five mortality, none of the DHS data sets considered in this assessment exhibits inconsistencies which make it clearly unsuitable for use in in-depth analysis of mortality in childhood.

## 4.6 Childhood Mortality Trends in Sub-Saharan Africa

### *4.6.1 Sahel West Africa*

Apparently no country within this region has recorded childhood mortality levels less than 100 per 1,000 live births, as shown in Figure 4.6. Mortality among children was heaviest in Mali up to around 1975 when it dropped to the level of Niger, which apparently maintained a similar level between 1970 and 1980. Up to the beginning of the 1970s, at least 30% of children born in these Sahelian countries were expected to die before reaching age five.

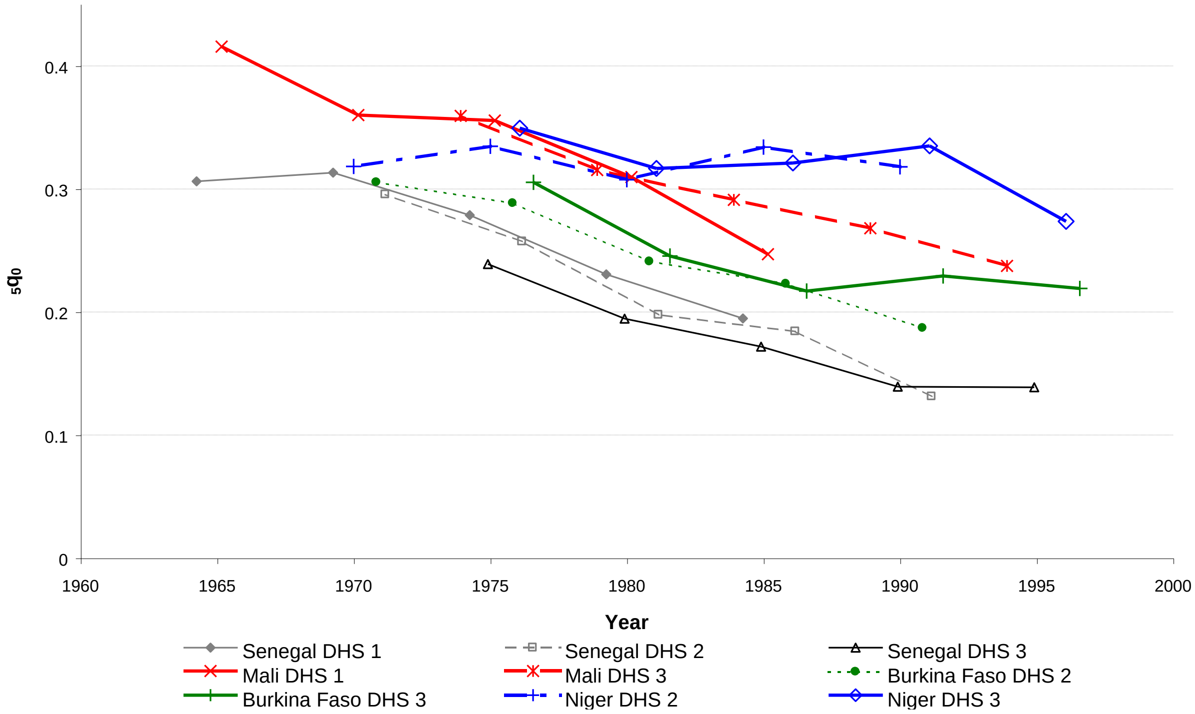



**Figure 4.6**: ***Under-5 mortality trends in Sahel West African countries: 1964 - 1996***

Whilst $_5q_0$ levels were almost similar in Senegal, Burkina Faso and Niger at the beginning of the 1970s at about 320 per 1,000, the stagnation of the level in Niger between 1970 and 1990 resulted in a significant gap in child mortality levels between the three countries in the early 1990s. About 200 more children per 1,000 die before reaching age five in Niger than in Senegal; and about 150 more per 1,000 in Burkina Faso.

With the exception of Niger, a steady decline in the level of $_5q_0$ was maintained from the early 1970s within the region. The rates of decline have been very similar in Senegal, Burkina Faso and Mali — identical gradients indicating drops of 6 to 7 deaths per 1,000 per annum. As a result, differences in mortality between these three countries have more or less been maintained over the years. The level in Niger remained virtually unchanged with an average rate of decline of about 0.5 deaths per 1,000 per annum between 1970 and 1990. However, even in the final five years of the last century, the level of $_5q_0$ was in excess of 200 per 1,000 in Mali and Niger.

### *4.6.2 Coastal West Africa*

Unlike the Sahelian West African countries, none of the countries in Coastal West Africa had under-five mortality of more than 300 per 1,000 by the beginning of the 1970s. However, $_5q_0$ levels were below 200 per 1,000 from the mid-1960s only in Ghana. As shown in Figure 4.7, under-five mortality in these countries was highest in Liberia and Guinea for the periods for which estimates are available for them. $_5q_0$ levels in these two countries ranged from about 290 per 1,000 in Liberia to about 180 per 1,000 in Guinea during the last three decades of the twentieth century.

Liberia and Benin recorded the same levels of under-five mortality in the late 1970s and early 1980s. In between these two countries with high childhood mortality for this region lie the other three neighbouring countries Côte d'Ivoire, Ghana and Togo. Figure 4.7 reveals that child mortality was less severe in Ghana between 1970 and 1995 than in its immediate neighbours in the west and east — Côte d'Ivoire and Togo — who had similar mortality over the period. This reveals a U-shaped geographical pattern of under-five mortality levels among these coastal West African countries — child mortality increases east and westwards from Ghana. The two Nigerian datasets show completely different levels of $_5q_0$ even for the

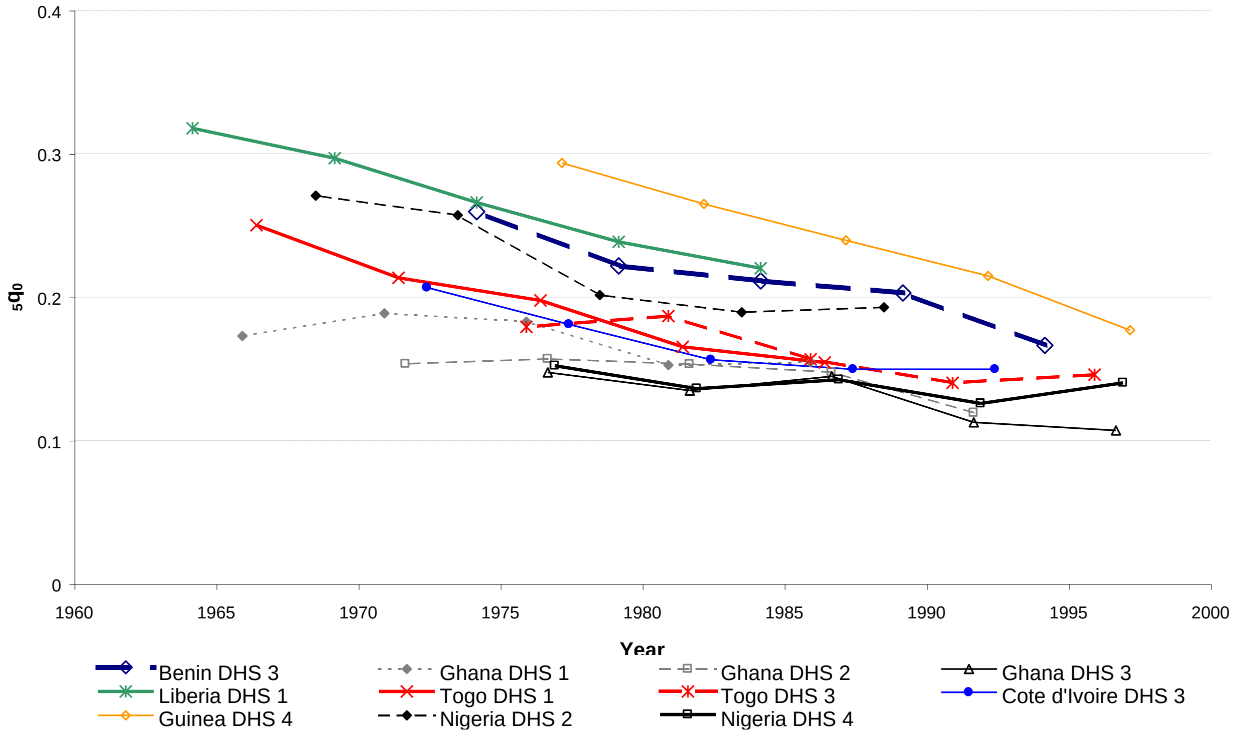



**Figure 4.7:** ***Under-5 mortality trends in Coastal West African countries: 1964 - 1997***

overlapping period of 1977 to 1989. With the absence of an independent dataset, it is difficult to judge between of the two trends depicted.

As far as average annual rates of decline in under-five mortality levels are concerned, the highest of about 5 per 1,000 per annum was recorded in Liberia between the mid-1960s and mid-1980s; and in Benin between the mid-1970s and mid-1990s. The countries (except for Guinea) with relatively lower under-five mortality levels recorded average rates of decline of less than 3 per 1,000 per annum in Ghana but slightly over 3 per 1,000 per annum in Côte d'Ivoire and Togo. As a result, differences in child mortality levels between these countries have narrowed considerably in recent periods (see Figure 4.7).

Unlike the Sahel West African countries considered earlier, none of the Coastal West African countries entered the last decade of the twentieth century with under-five mortality in excess of 200 per 1,000. However, levels below 100 per 1,000 are yet to be recorded in any of these countries.

### *4.6.3 Middle Africa*

With the exception of Cameroon, the direct estimates for the three Central African countries are from single surveys of each country. Thus, apart from the indirect estimates obtained from proportions dead of children ever born by age group of mother from the same surveys, no comparison can be made with another independent set of directly estimated levels of under-five mortality in Chad or Central African Republic. Notwithstanding this, and despite the unavailability of estimates dating as far back as 1970 for Chad and the Central African Republic, it is unlikely that any of these three Central African countries experienced under-five mortality as high as 300 per 1,000 by the late 1960s (see Figure 4.8), unlike those considered in Sahel West Africa.

From the available estimates, levels of ${}_5q_0$ have been slightly higher in Chad since the mid 1980s. Cameroon, on the other hand, recorded higher under-five mortality levels than the Central African Republic for about a decade from the early 1970s. But since childhood

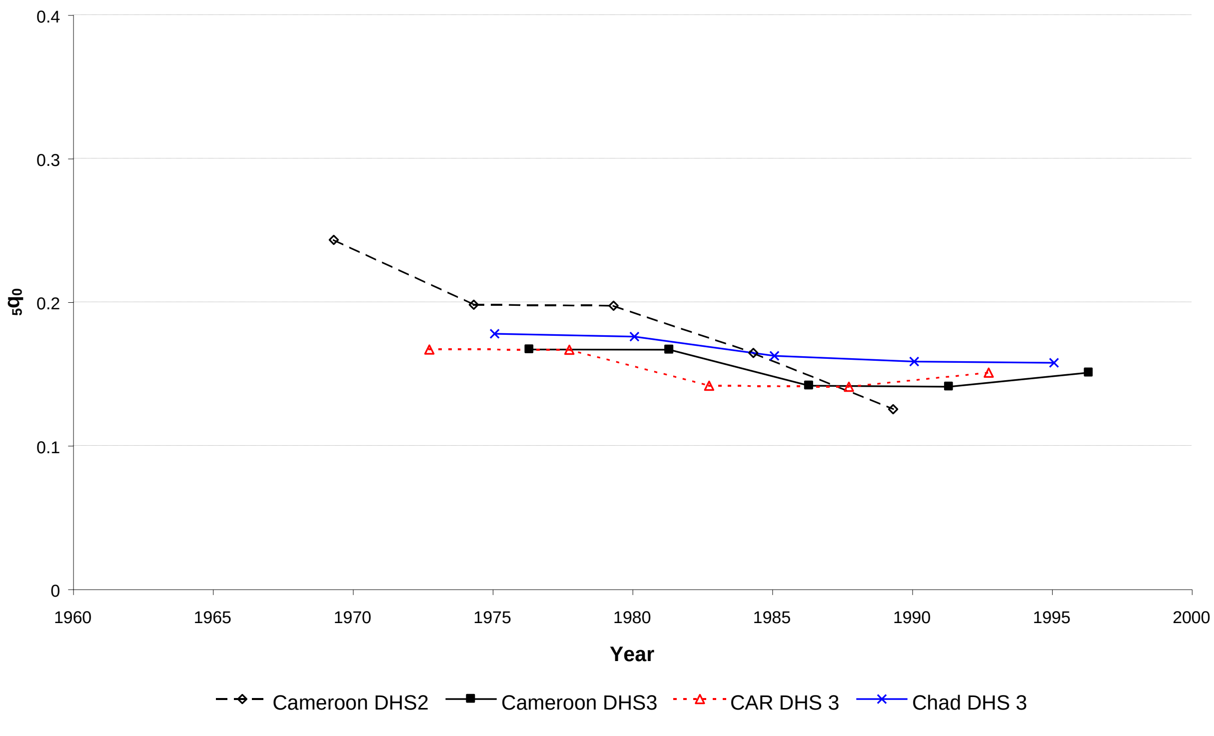



**Figure 4.8:** ***Under-5 mortality trends in Middle African countries: 1969 - 1996***

mortality in the latter country appears to have stagnated over the 25-year period for which estimates are available, Cameroon's relatively fast decline in under-five mortality — about 6 per 1,000 per annum, according to its second phase survey — reversed the difference in levels between the two countries from around 1984. By the beginning of the last decade, the Central African Republic was lagging slightly behind Cameroon in terms of under-five mortality.

The available estimates for these three Central African countries suggest that by the middle of the last decade none of them experienced ${}_5q_0$ levels in excess of 200 per 1,000. However, with the apparent stagnation of ${}_5q_0$ levels in Chad and slight trend reversals in the Central African Republic and Cameroon, one cannot expect the level in any of these countries to fall to less than 100 per 1,000 in the near future.

### *4.6.4 Eastern Africa*

From as far back as the late 1960s, under-five mortality has been well below the 300 per 1,000 mark in the East African countries. By the mid-1970s, only Rwanda and Ethiopia recorded levels of more than 200 per 1,000 (see Figure 4.9). Kenya has consistently recorded

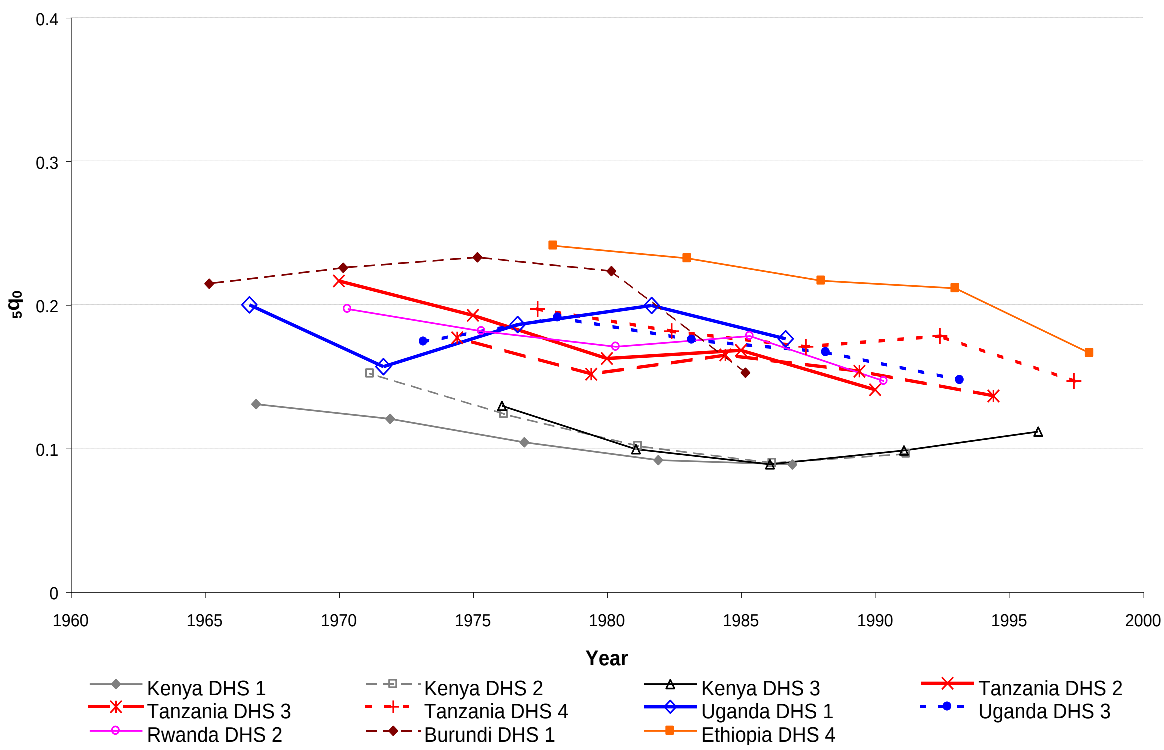



**Figure 4.9:** ***Under-5 mortality trends in Eastern African countries: 1965 - 1998***

the lowest level of ${}_5q_0$ among the four countries since the mid-1960s.

A close look at the trends in under-five mortality displayed by these countries reveals some interesting features. Although the Rwandan estimates were derived from a single survey, comparisons with the indirectly obtained estimates support the trend observed between 1980 and 1990 (see Figure 4.5). If, however, the direct estimates prior to 1980 are anything to go by, then there was a slight increase in ${}_5q_0$ among Rwandan children from about 240 per 1,000 in 1970 to a little less than 260 per 1,000 in 1975, after when a relatively fast decline was maintained down to the level of 150 per 1,000 in 1990. Whether the increase recorded between 1970 and 1975 represented the end of a longer period of increase in under-five mortality in Rwanda cannot be confirmed by the available data.

Focussing on Uganda and Tanzania, a scenario similar to that for Rwanda can be deduced but at different time lags. Even if the decline in Ugandan under-five mortality between 1966 and 1971 cannot be confirmed, there is clear evidence from the two Ugandan surveys that the level of ${}_5q_0$ did increase from about 170 per 1,000 in the early 1970s to about 200 per 1,000 in the early 1980s, before beginning a gradual decline to 140 per 1,000 just before the mid-1990s. While Uganda was experiencing the increase in child mortality from the beginning of the 1970s, Tanzania — which had heavier under-five mortality than Uganda up to around the mid-1970s — maintained a steady decline up to 160 per 1,000 in 1980 before beginning an increase similar to that experienced in Uganda about a decade earlier. The increase, however, was maintained for about five years only. Thus the peak in Tanzanian under-five mortality, at about 175 per 1,000 in 1985, is 12.5% less than the peak in Uganda. Mortality then fell to 130 per 1,000 in the mid-1990s.

Kenya maintained the lowest level of under-five mortality throughout the period for which estimates are available for these six Eastern African countries. Under-five mortality fell from about 170 per 1,000 in the early 1970s to 90 per 1,000 by the mid-1980s. From around 1986 an increase in ${}_5q_0$ became evident, rising to a level of about 110 per 1,000 in the mid-1990s (see Figure 4.9). This pattern can be likened to the experiences of Uganda and Tanzania.

### 4.6.5 *Southern Africa*

Until the beginning of the 1990s, Malawi had the highest levels of under-5 mortality in this sub-continental region as shown in Figure 4.10. The Mozambican $_5q_0$ estimates appear suspect. The corresponding indirectly obtained estimates did not corroborate the observed trend (see Figure 4.5), probably due to the assumption of linearity implicit in the indirect technique. In any case the trend suggests increasing under-five mortality between 1975 and 1995 from about 190 to 240 per 1,000. However, comparisons with Zambia — for which sufficient information is available — suggest the increasing trend might be genuine. Zambia clearly recorded moderately increasing under-five mortality between 1975 and 1990. Although the decline prior to 1975 cannot be confirmed by the available information, it appears as if the pattern observed among the eastern African countries also applies to Zambia and Mozambique, with an increase in $_5q_0$ setting in less than five years after Uganda, five years before Tanzania, and a decade before Kenya. There is no evidence that the increasing trend observed in the two southern African countries has yet ceased.

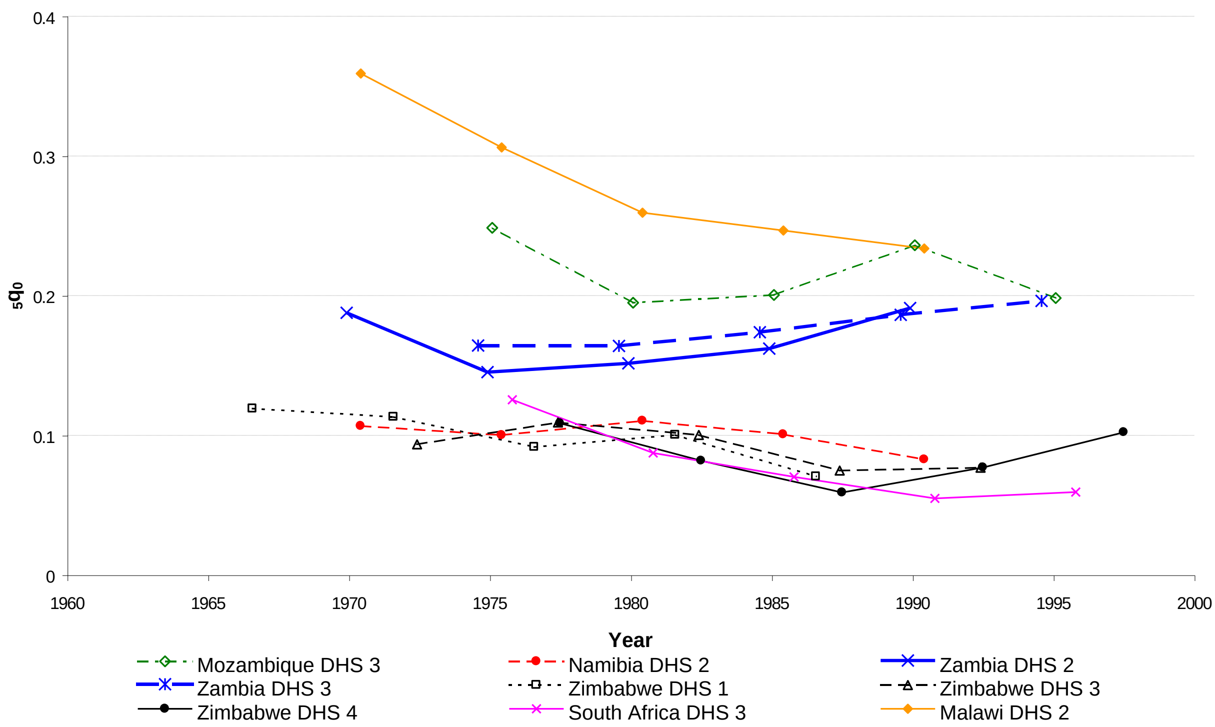



**Figure 4.10:** ***Under-5 mortality trends in Southern African countries: 1966 - 1997***

Zimbabwe, Namibia and South Africa, on the other hand, had similar and relatively lower levels of ${}_5q_0$ between 1970 and 1980. A slight gap seemed to have developed between the Zimbabwean and Namibian levels when Zimbabwe's rate of decline in under-five mortality got slightly steeper in the 1980s before stagnating towards the end of the 1980s and eventually increasing in the early 1990s. Both countries have had modest declines in ${}_5q_0$, viz.: from about 120 per 1,000 in Zimbabwe in the mid-1960s to 75 per 1,000 in the early 1990s; and from a little over 100 per 1,000 in Namibia in 1970 to about 80 per 1,000 in 1990. South Africa manifested a relatively somewhat larger decline in ${}_5q_0$ between 1975 and 1995. With the exception of Kenya in the eastern region which briefly recorded ${}_5q_0$ levels of less than 100 per 1,000, Namibia and South Africa are the only two countries among all those considered in the continent whose most recent levels of under-five mortality were below the 100 per 1,000 mark. Although the data series stops in 1990, there is no evidence to suggest reversal of under-five mortality decline in Namibia; but ${}_5q_0$ trend in South Africa appears to have reversed in the middle of the last decade.

## 4.7 Discussion

Birth histories constitute the best available source of data for the investigation of mortality patterns in childhood in Sub-Saharan Africa, which is characterised by a paucity of reliable demographic data. Assessing their quality essential for interpretation of the findings that will come from such an investigation. An attempt at this assessment is presented with a view to establishing the appropriateness of the birth histories of the respective national DHS datasets for exploring and identifying prevailing childhood mortality patterns in the continent. The data have been subjected to both internal and external tests, some of which simultaneously produced estimates of childhood mortality. These estimates enabled the reconstruction of the trends in ${}_5q_0$ for each of the countries considered. The main findings are summarised below.

### *4.7.1 Quality of Birth Histories*

Close observation of the sex ratios by age group of mothers revealed generally acceptable levels with a continental average of about 103 males per 100 females. On the basis of the individual datasets, no deficiency could be detected in the birth histories contained in the respective national Demographic and Health Surveys. With respect to tests focusing on proportions dead of children ever born and average parities by age group of mothers, all birth histories manifest the expected intrinsic feature of an increase with age of mothers for both indicators, except for the two Zambian datasets in the case of proportions dead of children ever born. However, comparison with other sets of similar indicators from independent sources such as censuses and other surveys revealed inconsistencies in the Malian, Kenyan and Zimbabwean DHS 1 datasets. These anomalies centre mainly on the indicators referring to the oldest mothers, i.e. 40-49 years old, and mainly affect mortality estimates for periods in time more than 15 years prior to the surveys. Since estimates for such periods are believed to be less reliable, the subsequent analysis is restricted to periods of not more than 15 years prior to the respective surveys. Other ways of checking the quality of the data are considered on an ad-hoc basis in the subsequent analysis of childhood mortality patterns.

### *4.7.2 General Trends in National Levels of ${}_5q_0$*

For the majority of the countries considered, the trends in under-5 mortality depicted by estimates from birth histories and other available sources reveal a consistent decline in the past up to the mid-1970s. This is in agreement with earlier observations made by Hill (1991a). Such declines were fastest in the West and Middle African countries and relatively modest in Eastern and Southern Africa. In the recent past, covering the period 1975-1995, national childhood mortality levels manifested different patterns of change. Many West and Middle African countries experienced relatively slow declines in ${}_5q_0$ during this period or near-stagnation. However, many in Eastern and Southern Africa show evidence of increases in ${}_5q_0$ levels since the latter half of the 1980s. The stagnation of levels being experienced by West and Middle African countries may be late response to a development effect — possibly economic decline — that has reversed trends in ${}_5q_0$ in parts of Eastern and Southern Africa. This assertion, however, can only be confirmed as more DHS data for West African countries become available.

An anomaly that could not be detected by the internal data checks adopted regarding the Nigerian DHS datasets was brought to light by the comparison of childhood mortality estimates derived from different independent sources. Although the direct and indirect ${}_5q_0$

estimates from the individual datasets match each other closely, collectively they depict inconsistent levels and trends. In fact, they do not overlap raising questions as to which dataset reflects the childhood mortality situation in Nigeria. For this reason, caution has to be exercised in the interpretation of results relating to patterns of mortality in Nigeria in the ensuing analyses.

### *4.7.3 Recent Levels of $_5q_0$*

Despite the differential rates of decline in childhood mortality, recent levels cluster into definite geographic entities with a few exceptions. Apart from Senegal, the Sahel West African region is characterised by $_5q_0$ levels in excess of 200 per 1,000. Another geographically contiguous area with similar mortality is the north-eastern part of Southern Africa covering Zambia, Malawi and Mozambique. Coastal West, Middle and Eastern African countries display recent levels of $_5q_0$ between 100 and 200 per 1,000. The lowest mortality of less than 100 per 1,000 was observed in the Southern African countries of South Africa and Namibia, with mortality only slightly over the 100 mark in Zimbabwe. The overall picture portrayed by this geographical distribution of national $_5q_0$ levels is a pattern of declining under-5 mortality south-eastwards from the Sahel West African region to the southern end Southern Africa if Zambia, Malawi and Mozambique are excluded. This is similar to the description of general mortality in Sub-Saharan Africa given by Hill (1991a) and Timaeus (1991; 1993).

The results presented in this chapter do not only portray DHS birth histories as useful and reasonably reliable data sources for the investigation of mortality patterns within the first five years of life, but also reveals the dynamism surrounding childhood mortality in the continent. This indicates that variations in the age pattern of mortality in childhood across the continent probably exist.

# Chapter 5

# Prevailing Mortality Patterns in Childhood and their Geographical Distributions

## 5.1 Introduction

Assessment of the suitability of the DHS birth histories for use the investigation of the nature and distinctive characteristics of child survival in Sub-Saharan Africa sets the scene for a comprehensive exploration of age patterns of mortality within the first five years of life. The flexibility of the birth histories, unlike the information on proportions of children surviving by age group of mothers, enables the computation of age-specific mortality indicators, thus making it possible for mortality schedules of different populations to be compared and contrasted.

The ensuing analysis of mortality patterns in childhood starts with an exploratory graphical approach using the direct childhood mortality indicators computed in the previous chapter and presented in Appendix 2. The exploration aims at answering the following questions *inter alia*:

- What types of patterns of mortality in childhood prevail in the continent and what are their distinctive characteristics?

- As reflected in the national ${}_5q_0$ trends, does the dynamism of childhood mortality in the continent manifest itself in the prevailing patterns of mortality? In other words, are time variations in mortality patterns evident among national and sub-national populations where the level of under-5 mortality has changed?

- Do their respective geographical distributions follow international boundaries or do they cluster into contiguous geographic entities that cover sub-national regions of different adjacent countries?

## 5.2 Method of Mortality Pattern Assessment

Demographers have not been endowed with many robust non-statistical techniques of assessing mortality patterns, especially with respect to an established standard model. As could be deduced from the review of the literature regarding levels and patterns of childhood mortality, researchers have used a rather narrow range of methods comprising of:

i. a ${}_5q_0$ "level"-only comparison technique;
ii. an ${}_nm_x$-based graphical comparison for two or more populations; and
iii. a graphical comparison of ${}_1q_0$ and ${}_4q_1$ relationships against those of standard model life tables for one or more populations.

Root (1999), for instance, used levels of ${}_5q_0$ only in an assessment of what he termed patterns of under-5 mortality in sub-national regions of Sub-Saharan African. But as can clearly be seen from Figure 3.3, the ${}_nq_x$ contours indicate that different populations can manifest different patterns of mortality within childhood at the same level of under-5 mortality. Thus, if the aim of the assessment is to arrive at the closest known pattern of mortality manifested by the population or populations in question, then levels alone will not be sufficient.

Cantrelle and Leridon (1971) and Hill *et al*. (1983) compared childhood mortality patterns of two or more populations by plotting their respective age-specific death rates on a common graph and comparing the resulting schedules. This is how Cantrelle and Leridon observed the differences in age-specific mortality levels in childhood between a Senegalese population and an historical European one. Hill *et al*. also used the same approach to demonstrate that the pattern of mortality observed by Cantrelle and Leridon differed from that prevailing among various ethnic groups in neighbouring Mali. Despite the credibility demonstrated by the method, its use to compare and identify the depicted pattern of mortality for up to twenty populations would prove very cumbersome. It will nevertheless be extremely useful in instances where the aim is to classify age-specific mortality schedules of different populations into groups with specified distinct features. It is for this purpose that this method is used extensively in Chapter 6.

Using survey data mainly, Blacker *et al*. (1985), Hill (1995), and Bicego and Ahmad (1996) based their explorations of childhood mortality patterns on the third method highlighted above, i.e. the comparison of infant to child mortality relationships against those of four families of the Princeton model life tables. In addition to facilitating comparison of specific populations with the standard Princeton models, the method is also capable of charting the changing circumstances of the levels of infant and child mortality over time for the defined populations concerned. For these reasons, this method is judged suitable for the task at hand, and is adopted to facilitate the identification and selection of the established Princeton patterns of mortality in childhood closest to the patterns depicted by national and sub-national populations.

### *5.2.1 Description of Adopted Method*

In this Chapter, age patterns of mortality in childhood are explored by investigating the relationship between the levels of infant (${}_1q_0$) and child (${}_4q_1$) mortality, i.e. the distribution of the probabilities of dying between these two age brackets at any given level of overall under-five mortality. The patterns are analysed using a graphical approach with each probability of dying between the exact ages 1 and 5 plotted against its corresponding probability of dying by age 1. Estimates from the same survey, but for different time periods — i.e. 0-4, 5-9 and 10-14 years prior to the survey — are joined by straight lines and juxtaposed with the standard infant-to-child mortality relationships of the four Princeton families of model life tables for both sexes (as shown in Figure 3.4) to facilitate the process of mortality pattern identification for geographical units that each set of estimates refers to. These lines will run diagonally downwards from the right to the left as mortality declines, and the reverse will hold in instances of rising childhood mortality. As already noted in Chapter 3 (section 3.4.2), the standard Princeton relationships show the "North" family as the pattern with highest child mortality relative to infant for ${}_1q_0$ values of less than about 160 per 1,000 (beyond which it is the "South"), followed by the "South", "West" and "East" families.

The investigation is conducted at the national and sub-national levels with a view to delineating geographic entities that display different mortality patterns based on this mode of assessment. The national population, being the unit of analysis for most previous studies, is updated with evidence emanating from recently available third and fourth phase DHS datasets. Much attention however is placed on analysis at the sub-national level, i.e. sub-national populations defined by region of residence only. This will facilitate a cartographical representation of observed Sub-Saharan childhood mortality patterns without being restricted by international political boundaries.

### *5.2.2 Source of Infant and Child Mortality Estimates*

The infant and child mortality estimates used in the ensuing analysis are derived from the birth histories in the respective national DHS datasets using the direct estimation technique explained in detail in the previous chapter (refer to Sections 4.2 and 4.3). Instead of restricting estimates to the five-year period prior to each survey as in Chapter 4, three sets of estimates referring to the three consecutive quinquennia prior to each survey — as presented in Appendix 2 — are included in the analysis. Although the estimates for the periods 15-19 and 20-24 years before each survey are also available, they are less reliable because they are more predisposed to recall error as pointed out earlier. It is therefore considered prudent to exclude them from the analysis. The same procedure was adopted to directly estimate infant and child mortality indicators for the three most recent quinquennia before each national survey for 165 sub-national regions in the 26 countries involved in the study.

### *5.2.3 Criteria for Pattern Identification and Selection*

A set of criteria is used to guide the selection of the model mortality patterns depicted by the respective national and sub-national populations. Provided the three respective points representing the three quinquennia and describing the relationship between child and infant mortality fall within the range traced out by the Princeton model patterns, the following pattern selection criteria are adopted:

i. If the three points closely follow one pattern, that pattern is selected.
ii. If the two most recent points follow a particular pattern and the third significantly falls off course, the pattern followed by the most recent points is selected.
iii. If the most recent point falls off significantly from the other two which satisfactorily follow a particular pattern, and that the change it depicts is

considered to be infeasible within a five-year period, then the pattern followed by earlier two points is selected.

iv. If the three points do not, collectively or in pairs, follow any particular pattern, the model pattern closest to the most recent point is selected.

If, however, all or some of the points fall outside the boundaries of the Princeton “North” and “South” model patterns, they are classified as “unusual” because of the significantly high level of child mortality relative to infant compared with the model patterns.

### *5.2.4 The Effect of Heaping on Age at Death*

As explained in Section 4.1, “recall” error resulting from shifts in birth and death dates can have a significant impact on childhood mortality patterns derived from birth histories. Probably the most worrying problem of data error introduced by mothers incapable of remembering the exact dates of events pertaining to their children is heaping on age at death for dead children. In the national DHS datasets pooled for this analysis, heaping in relation to age at death mainly occurs on ages that are multiples of 6 months up to 24 months, with the bulk falling on age 12 months. Many deaths occurred as early as 9 months of age or as late as up to 15 months may have been reported as having occurred at age 12 months. This is especially so for such deaths that occurred well before the survey. Undoubtedly, such a situation has potential to yield a deceptive distribution of deaths between the exact ages 0 and 12 months on the one hand, and 12 to 60 months on the other, and consequently a wrong age pattern of mortality. The question that comes to mind, therefore, is what is the nature and significance of the errors introduced by heaping of age at death on 12 months for the intended analysis? Is there an appropriate and efficient method of eliminating the errors completely or to at least curb the cumulative effect to an insignificant level?

The demographic literature does not have any method on record that corrects this problem with a high degree of precision. In their assessment of the magnitude of the problem in Phase 1 DHS datasets, Macro International (1993) opined that any attempt to determine the extent of heaping has to assume knowledge of an "expected" number of deaths at 12 months of age, which in turn assumes knowledge of the true age pattern of mortality as well as the age range from which the heaped death are drawn. However, a technique devised by Brass and Blacker

(1999) for estimating infant mortality from proportions dying among recent births has proven useful in interpolating life table measures for ages within childhood by fitting a mathematical model between any two specified ages in childhood. The fitted model essentially smooths the survival curve between the specified ages, thus implying that it has the potential of correcting errors such as those caused by heaping of age at death on 12 months.

They propose that mortality over the first few years of life can be well represented by the simple function

$$l(x) = (1 + \alpha x)^{-\beta},$$

where $x$ is age in either years or months; and $\alpha$ and $\beta$ represent the level and pattern of mortality respectively. They noted that the nature of these two coefficients can be demonstrated better in terms of the force of mortality at age $x$, $\mu(x)$. By taking logs and differentiating the above equation with respect to age $x$, one obtains

$$\ln l(x) = -\beta.\ln(1+\alpha x),$$

thus giving

$$\mu(x) = \alpha\beta/(1+\alpha x) = \mu(0)/(1+\alpha x).$$

It is clear from this result that $\alpha$ determines the pace of fall in mortality with age, while $\beta$ adjusts for the level. Given any two values of $l(x)$ for any life table, say $l(x_1)$ and $l(x_2)$, the model can be fitted with the value of $\alpha$ derived iteratively from a relationship involving the ratio, $R$, of the logarithms of the $l(x)$ values at ages $x_1$ and $x_2$. This relationship is

$$R = \frac{\ln l(x_1)}{\ln l(x_2)} = \frac{\ln(1 + x_1\alpha)}{\ln(1 + x_2\alpha)}$$

The value of $\beta$ is given by $-\ln l(x_2)/\ln(1+ x_2\alpha)$. Brass and Blacker recommended that the two ages, $x_1$ and $x_2$, at which to fit the model be determined empirically.

With a view to determining the extent to which the DHS datasets are affected by the problem of heaping, the technique is applied here to the life tables derived from all surveys of Senegal, Ghana and Kenya. These life tables span birth to age 24 months, and refer only to the five-year period before the respective surveys. The countries were selected on the bases that they have three independent datasets each and are located in different sub-continental regions as defined in this study with different overall levels of child mortality. In each case the relevant model was fitted between the ages of 9 and 15 months, the fitted $l(x)$ value for age 12 months obtained by interpolation and the adjusted level of ${}_1q_0$ computed. This new estimate of ${}_1q_0$ is then used in combination with the published estimate ${}_5q_0$ for the period and country concerned to derive the corresponding level of ${}_4q_1$. The unadjusted and fitted levels of ${}_1q_0$ and ${}_4q_1$ are presented and compared in Table 5.1.

The highest proportion of infant deaths added to the observed number as a result of the adjustment is 11%. Also, the high proportions of 10% in the case of Senegal and 11% for Ghana are associated with first round DHS surveys and high levels of under-5 mortality. There is evidence to suggest that later surveys may be less affected by heaping of age at death on 12 months — probably due to improvements made in survey methods and interviewing techniques in the later phases of the DHS programme. In absolute terms, the number of deaths involved in the respective adjustments range from zero to nine for under-5 mortality levels of between 96 and 190 per 1,000 live births. Heaping of this magnitude can have some effect on the assessment of age patterns of mortality in childhood on the bases of ${}_1q_0$ and ${}_4q_1$, thus

**Table 5.1:** ***Comparison of heaping-adjusted levels of ${}_1q_0$ and ${}_4q_1$ with unadjusted levels.***

| Country / Survey | | Infant Mortality Rate† | | | Child Mortality Rate* | | |
|---|---|---|---|---|---|---|---|
| | | Unadjusted | Adjusted | % Change | Unadjusted | Adjusted | % Change |
| Senegal | | | | | | | |
| | *DHS 1* | 87.6 | 96.3 | ***10%*** | 113.1 | 104.6 | ***-8%*** |
| | *DHS 2* | 67.9 | 68.0 | ***0%*** | 68.0 | 67.8 | ***0%*** |
| | *DHS 3* | 67.6 | 73.4 | ***9%*** | 76.4 | 70.6 | ***-8%*** |
| Ghana | | | | | | | |
| | *DHS 1* | 75.7 | 83.9 | ***11%*** | 85.3 | 77.0 | ***-10%*** |
| | *DHS 2* | 66.4 | 69.3 | ***4%*** | 56.6 | 53.6 | ***-5%*** |
| | *DHS 3* | 58.1 | 61.3 | ***6%*** | 51.8 | 48.6 | ***-6%*** |
| Kenya | | | | | | | |
| | *DHS 1* | 61.0 | 63.3 | ***4%*** | 29.3 | 26.9 | ***-8%*** |
| | *DHS 2* | 61.8 | 63.8 | ***3%*** | 36.5 | 34.4 | ***-6%*** |
| | *DHS 3* | 73.1 | 75.8 | ***4%*** | 41.4 | 38.7 | ***-7%*** |

† *per 1,000 live births;* * *per 1,000 population*.

posing a problem to the analysis focussing on child/infant mortality ratio. However, the effect is not large enough to render the intended analysis inappropriate. Besides, any attempt of correcting the errors caused by heaping will render the results incomparable with previous studies (Blacker et al., 1985; Hill, 1995) which did not apply any technique of heaping correction. Moreover, making the adjustment for every quinquennium would require the preparation of a life table ranging from birth to 24 months of age, fitting a model and the deduction of $l(12)$ iteratively. Repeating the process 132 times (i.e. 3 quinquennia by 44 national DHS datasets) to adjust national infant and child mortality estimates would be time demanding and the outcome may not be different from the situation already demonstrated. It is unthinkable to attempt it more than a thousand times when considering sub-national regions involved in the study. For these reasons, it is decided to proceed with the assessment of childhood mortality patterns at national and sub-national levels using the unadjusted estimates of infant and child mortality.

## 5.3 Results

For ease of comprehension, the results from the graphical assessment of childhood mortality patterns are presented separately for the different geographical units used in the analysis, viz.: the national, (at the level of the country); and the sub-national, (i.e. at the local regional level within a country). The results emanating from the sub-national analysis lend themselves to an appraisal of the dynamism of childhood mortality patterns in the continent through a mapping process that assesses changes in regional mortality patterns between any two consecutive surveys. Three countries are used as examples for this purpose. They are Ghana, Kenya and Zambia. The mapping process finally considers all the countries included in the study by indicating the most recent childhood mortality pattern observed in each sub-national region of all the countries included in the study.

### *5.3.1 National Patterns of Mortality in Childhood*

As in the previous chapter, the observed national childhood mortality patterns are presented using the sub-regional groupings of the continent employed earlier. The patterns depicted by data obtained from the respective phases of the DHS programme, are shown in a single graph and described separately for each sub-region. Thus facilitates comparison between countries of the same region of the continent. The mode of presentation provides another opportunity to check for consistency in the respective national datasets for countries with more than one survey. Since only three countries are classified under Middle Africa, this region is considered together with Coastal West Africa.

*Sahel West Africa*

Figure 5.1 shows the relationship between ${}_4q_1$ and corresponding ${}_1q_0$ estimates obtained from nine surveys conducted in the four countries that constitute Sahel West Africa as defined in this study. The most striking feature of the graph is that none of the nine surveys yielded infant to child mortality relationships that fall within the range of the Princeton families of model life tables. For all four countries, child mortality has remained consistently higher relative to infant mortality than would be expected of the "North" pattern of childhood mortality, and even the "South" pattern for ${}_1q_0$ estimates of more than 160 per 1,000 live births. This is especially so for Senegal and Niger, which have extremely high levels of child mortality; whereas the patterns for Mali and Burkina Faso follow the "North" pattern but at slightly higher levels of child mortality.

Although these observed rather extreme patterns of childhood mortality are consistent with earlier observations in the little literature available (Blacker *et al*., 1985; Hill, 1995) — in part because some of the earlier datasets used here were also used in these previous studies — one may still posit they are as a result of data error. This seems unlikely on two grounds. The first line of argument focuses on the consistency of the infant to child mortality relationships obtained from independent surveys conducted at different times in the same country. Even though a set of consecutive birth histories are not expected to produce points that link up smoothly, the three Senegalese datasets especially show a high degree of consistency, thus providing sufficient evidence to confirm their individual as well as collective reliability. The two datasets for Niger are only five years apart and the similarity and closeness of their respective sets of points is another confirmation of the near stagnation of childhood mortality in the country as noted in the previous chapter. The two surveys from Mali disagree about the level of ${}_4q_1$ despite having been conducted a decade apart. The last point derived from the

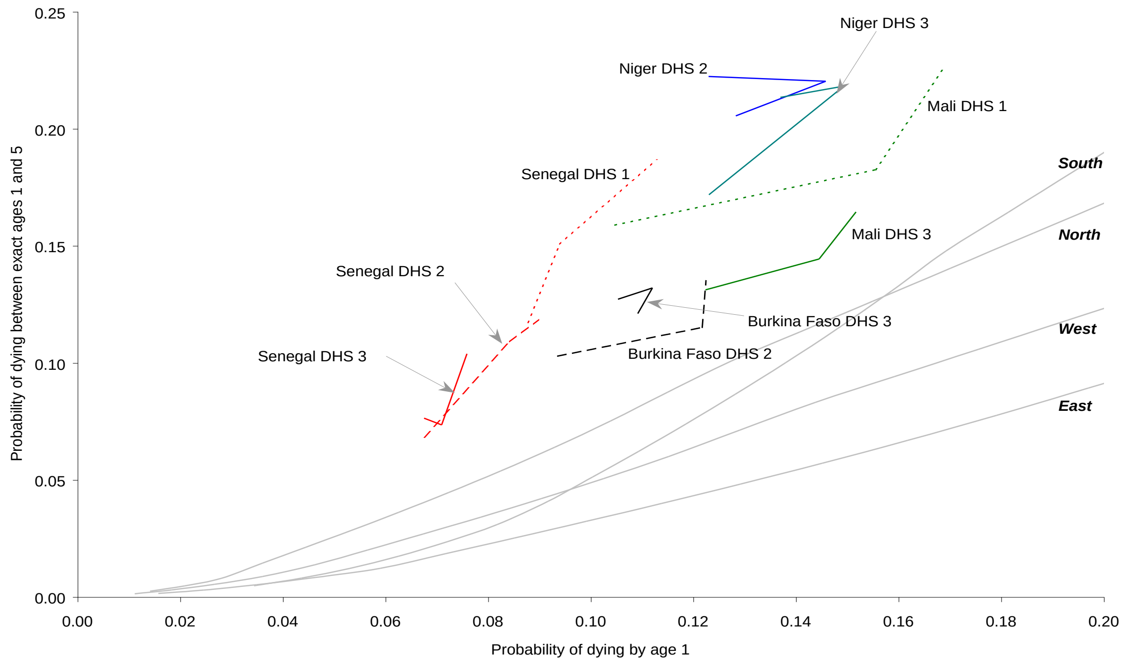



**Figure 5.1:** ***Observed national age patterns of childhood mortality in Sahel West African countries by DHS phase***
***Sources: Computed from respective National DHS datasets.***

DHS1 dataset appears suspect because of the significant drop in infant mortality it indicates between 5 and 9 years prior to the survey. The two Burkinabe surveys, unlike those of the other three countries, manifest a degree of inconsistency in terms of depicted trend in pattern of childhood mortality caused probably by the increase in overall childhood mortality level between the two surveys — a rather surprising finding for a country in this part of the continent. Notwithstanding, the patterns shown by both datasets are consistent in the much higher child mortality levels they indicate relative to infant than one would expect in the Princeton "North" family of model patterns.

The second argument is that the depicted patterns collectively trace out two trends that possibly depict the relationship between child and infant mortality. Whilst the points from the Burkinabe and Malian surveys trace out a pattern of high child mortality relative to infant that runs parallel to the Princeton "North" pattern, those from the other two countries — i.e. Senegal and Niger — delineate a much more extreme pattern of high child mortality relative to infant. It can be suggested, therefore, that the characteristics of the declines in childhood mortality differ between these neighbouring countries. Whilst significant improvements have been made with respect to child mortality in Senegal as general mortality falls, the drops in ${}_4q_1$ in Mali and Burkina Faso do not correspond with as significant drops in ${}_1q_0$, despite showing rates of decline in mortality in both age groups similar to those of the Princeton "North" family, but at slightly higher levels.

*Coastal West and Middle Africa*

In the Coastal and Middle African countries, three out of fifteen DHS datasets display national childhood mortality patterns that fall within the range of the Princeton model families (see Figure 5.2). These are Liberia, Côte d'Ivoire and Central African Republic. Whilst Liberian DHS1 dataset indicates a "West" pattern of mortality in this country, neighbouring Côte d'Ivoire and the Central African Republic display childhood mortality

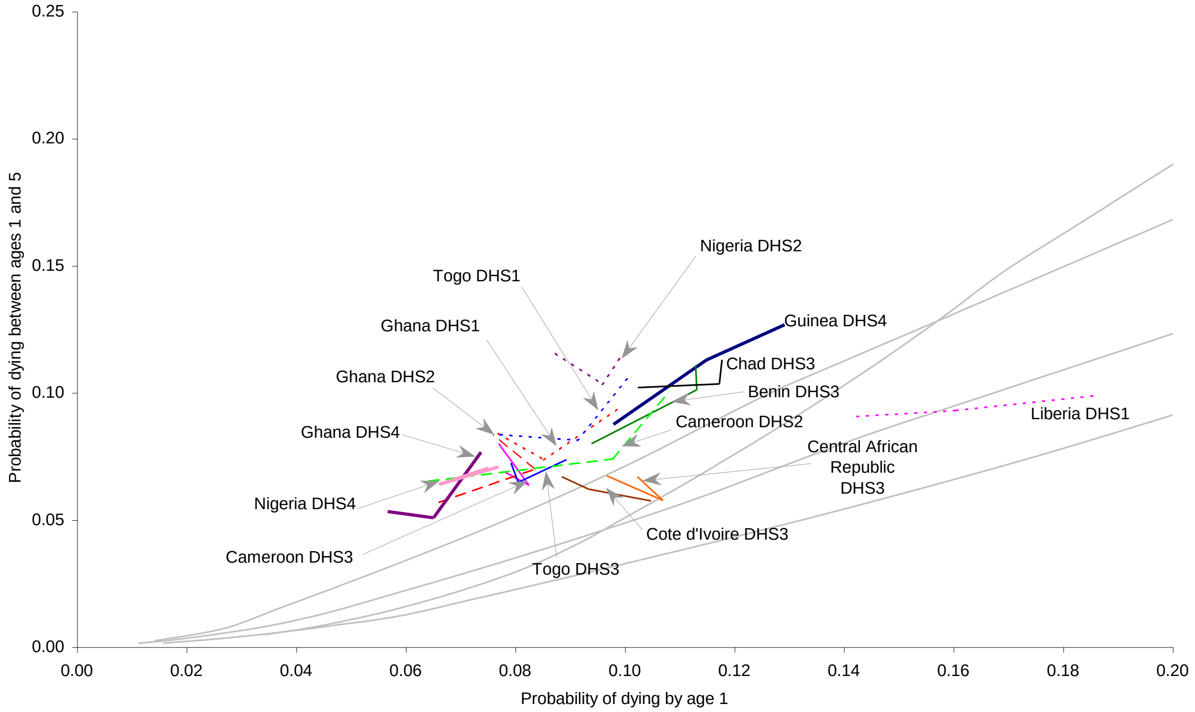



**Figure 5.2:** ***Observed national age patterns of childhood mortality in Coastal West and Middle African countries by DHS phase.***
***Sources: Computed from respective National DHS datasets.***

patterns somewhere between the Princeton “North” and “South”. The remaining twelve countries, like the Sahel countries considered earlier, manifest national patterns of mortality in childhood characterised by slightly higher child mortality relative to infant than is the case in the Princeton “North” family, with the Nigerian DHS2 dataset indicating a rather more extreme form of the pattern. With the exception of this dataset, i.e. Nigeria DHS 2, all the points from the other eleven datasets cluster within a narrow band that runs slightly above and parallel to the Princeton "North" pattern. As in Senegal and Niger in Sahel West Africa, the consistency of the child to infant mortality relationship points from consecutive surveys in the cases of Ghana, Togo and Cameroon indicates that this is not as a result of data error. The Nigerian datasets, on the other hand, depict a marked difference in ${}_5q_0$ levels over a period of about a decade. The lack of overlap between the two sets of points tends to suggest that there are problems with one or both Nigerian datasets. Notwithstanding, they portray a similar pattern of mortality at different levels of mortality.

The geographical distribution of the observed patterns in these countries is worth mentioning. The contiguous entity comprising of Ghana, Togo, Benin, Nigeria, Chad and Cameroon shares the same unusual pattern of slightly higher child mortality relative to infant, whilst Liberia and Côte d’Ivoire in the west and Central African Republic in the east have patterns within the Princeton range — between “North” and “South” for Côte d’Ivoire and Central African Republic; and “West” for Liberia. Guinea, which borders both Liberia and Côte d’Ivoire, manifest a pattern of mortality in childhood similar to that of the large group of countries. A possible issue of contention here is the difference in childhood mortality pattern between Liberia and Côte d’Ivoire on the one hand, and Guinea, Ghana and the rest of the contiguous group on the other hand. Although the Liberian dataset dates back to the mid 1980s, the 1994 dataset for neighbouring Côte d’Ivoire also indicates an apparent difference between the experiences of these two countries in Coastal West Africa and those to the east. Thus the rather conspicuous Liberian childhood mortality pattern may not be as a result of data error. This issue is explored further in subsequent sections of this chapter.

*Eastern Africa*

A scenario similar to that of the Coastal and Middle African countries in terms of childhood mortality patterns displayed also obtains among the twelve surveys from seven Eastern African countries. This includes the 1995 Eritrean survey whose child to infant mortality relationship points were obtained from the published report (see National Statistics Office [Eritrea] and Macro International, 1997). However, a higher proportion of the Eastern African datasets — seven out of twelve — reveal childhood mortality patterns within or very close to the Princeton range of model patterns (see
Figure 5.3).

At very low — but recently rising — levels of overall childhood mortality, Kenya's pattern of mortality in childhood has transformed from Princeton "North" to somewhere between "North" and "West". Tanzania, with relatively higher overall childhood mortality, similarly had its mortality pattern in childhood change from a near "North" trend to "South". With yet higher childhood mortality, the Ethiopian dataset suggests a changing pattern of childhood

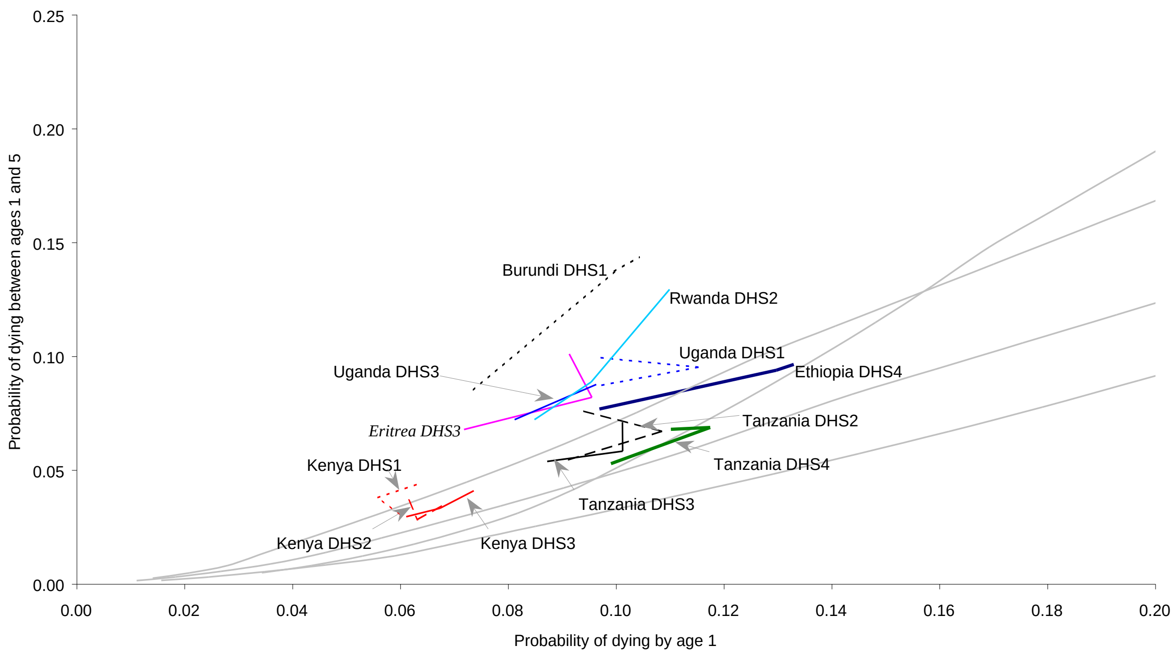



**Figure 5.3:** ***Observed national age patterns of childhood mortality in Eastern African countries by DHS phase***

***Sources: National Statistics Office [Eritrea] and Macro International (1997) for Eritrea; others computed from respective National DHS datasets.***

mortality from “South” to “North” as its overall childhood mortality fell. Uganda, Rwanda Burundi and Eritrea manifest patterns that are rather unlike those of Kenya and Tanzania, but similar to those observed earlier for the majority of West African countries. Whilst Burundi shows a pattern of extremely high child mortality relative to infant — a typical pattern in the Sahelian countries, Uganda, Rwanda and Eritrea show the pattern of slightly high child mortality relative to infant mortality.

The above description results in a geographical distribution of childhood mortality patterns in Eastern Africa that depicts the western part of the region covering Burundi, Rwanda and Uganda as a contiguous geographical unit where child mortality is higher relative to infant than in the Princeton “North” pattern. The rest of the region, except for Eritrea in the north, manifests Princeton type patterns of childhood mortality.

In terms of consistency among datasets,
Figure 5.3 shows that the sets of child to infant mortality relationship points from the three datasets of Kenya and Tanzania cluster very close together, thus suggesting that the data are highly reliable. The sets of points from the two Ugandan datasets also overlap neatly. The countries with single datasets cannot be judge by themselves for errors, but their respective child to infant mortality relationship points seem reasonable in comparison with countries with multiple datasets. There is no reason, therefore, to doubt their quality.

*Southern Africa*

Southern Africa is the part of the continent where the lowest levels of childhood mortality prevail, although pockets of relatively high under-five mortality also exist. However, it is also the sub-region worst affected by the AIDS epidemic. Like the East African region, seven out of ten datasets from seven countries yield childhood mortality patterns that can be described by Princeton families of model life tables as shown in Figure 5.4 — the highest proportion in the five sub-regions of the continent considered. It should be noted that Botswana is included at this level of the analysis only to provide a complete picture of the situation of childhood mortality patterns in the region. The data relating to its level of child and infant mortality

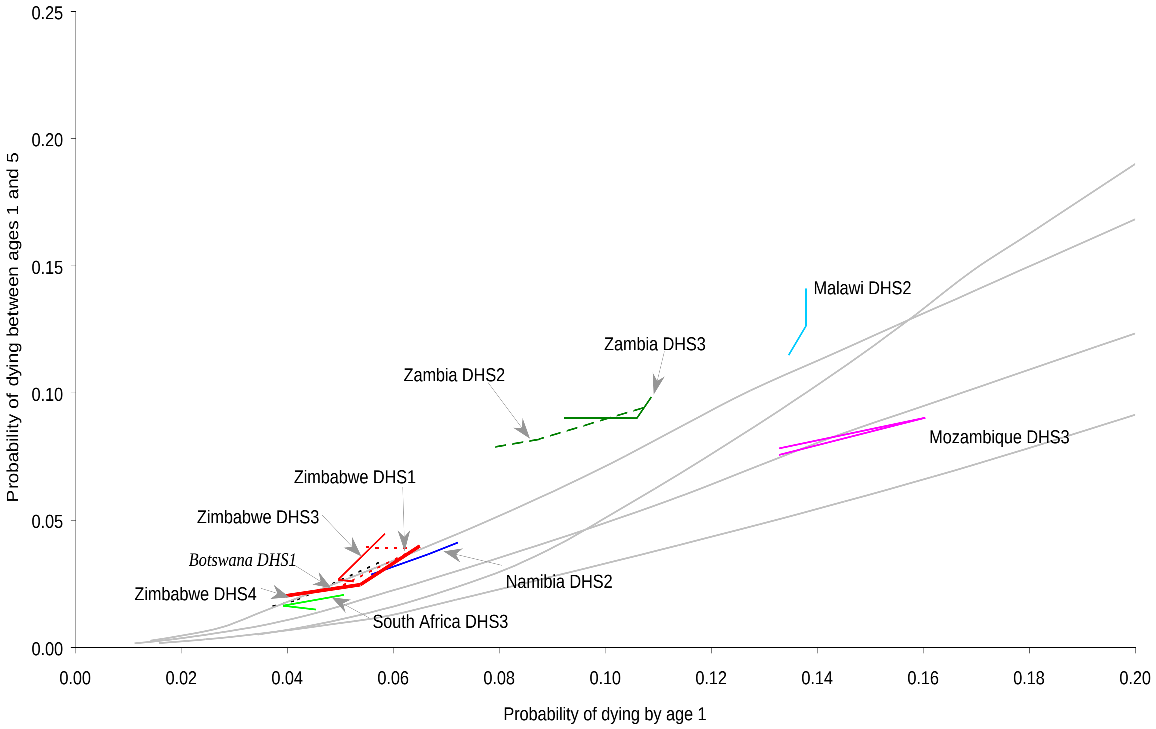



**Figure 5.4:** ***Observed national age patterns of childhood mortality in Southern African countries by DHS phase***

***Sources: Central Statistics Office [Botswana] and Macro International (1989) for Botswana; others computed from respective National DHS datasets.***

were obtained from the published report of its second Family Health Survey conducted in 1988 (see Central Statistics Office [Botswana] and Macro International, 1989).

As far as childhood mortality patterns are concerned, the region is no exception to variations as observed in the other continental sub-regions discussed earlier. The main significant difference with the other sub-regions is the absence of the pattern of extremely high child mortality relative to infant mortality. The low mortality countries, i.e. South Africa, Namibia, Botswana and Zimbabwe, demonstrate child to infant relationship points that cluster together close to the bottom left corner of the graph. Those with high childhood (i.e. under-5) mortality, i.e. Malawi and Mozambique, display points at the opposite end of the spectrum. Zambia, with an intermediate level of overall childhood mortality, yields points that lie between the extremes.

As can be seen clearly in Figure 5.4, the three surveys from Zimbabwe consistently depict a Princeton "North" pattern of mortality in childhood despite the apparent steady increase in overall under-five mortality that the individual datasets indicate. The overlapping of infant-to-child relationship points from the respective Zimbabwean datasets is indicative of the reasonable quality of the birth histories contained in them. Neighbouring Botswana and Namibia in the west, with one dataset each, also trace out the Princeton "North" pattern. Further south, the South African DHS3 dataset outlines a childhood mortality pattern that has transformed from one very close to Princeton "West" to "North" and back to "West" as overall childhood mortality started increasing in the ten-year period prior to the survey. On the basis of their geographical proximity and similar depicted pattern of mortality in childhood, it seems likely that these datasets are also of reasonable quality.

At the other end of the spectrum, Mozambique traces out a "West" pattern of childhood mortality whilst neighbouring Malawi reveals the unusual pattern characterised by slightly higher child mortality relative to infant than is the case in the Princeton "North". Zambia has a pattern similar to that of Malawi, but at a relatively lower level of overall childhood mortality. The two Zambian datasets neatly overlap, allaying doubts of their quality. Not much can be said, though, about the Mozambican dataset with regards to its quality. As was noted in the previous chapter, external consistency checks on this dataset did not yield any clear-cut outcomes either (refer to section 4.5 and Figure 4.5). Whilst its depicted pattern of childhood mortality differs from those in the geographically contiguous three countries that constitute the northern and eastern parts of this sub-region, it is similar to that of neighbouring South Africa.

It is apparent from the foregoing descriptions of national childhood mortality patterns for the respective sub-regions of the continent that significant differences exist between countries within the same sub-regions, and between sub-regions in terms of the most prevalent and general distribution of mortality patterns. The extent of such differences is illustrated by Figure 5.5, which pools the available information on the relationships between child and infant mortality for all countries using the estimates derived from all datasets included in the study. They are coloured according to sub-region. A number of significant issues emerge from the graph. First, only 17 out of a total of 46 datasets used (including those from Eritrea and Botswana) — representing about 37% — have a relationship between infant and child mortality that falls within the range of the Princeton model system of life tables. This implies that up to 60% of national childhood mortality patterns in Sub-Saharan Africa cannot be adequately represented by Princeton model life tables.

Second, there is a general trend for deviation from the Princeton patterns to increase northwards from Southern Africa. More datasets from Southern African countries yielded Princeton childhood mortality patterns than any other sub-region, followed by Eastern African countries, then Coastal and Middle West African countries; while the Sahel West African states present the most extreme forms of childhood mortality pattern characterised by exceptionally high child mortality relative to infant mortality. The cases of Burundi in Eastern Africa and Malawi in Southern Africa are exceptions worth noting.

Finally, observed patterns of childhood mortality that fall outside the range of the Princeton model families appear to concentrate along two distinct paths that can be regarded as the infant-

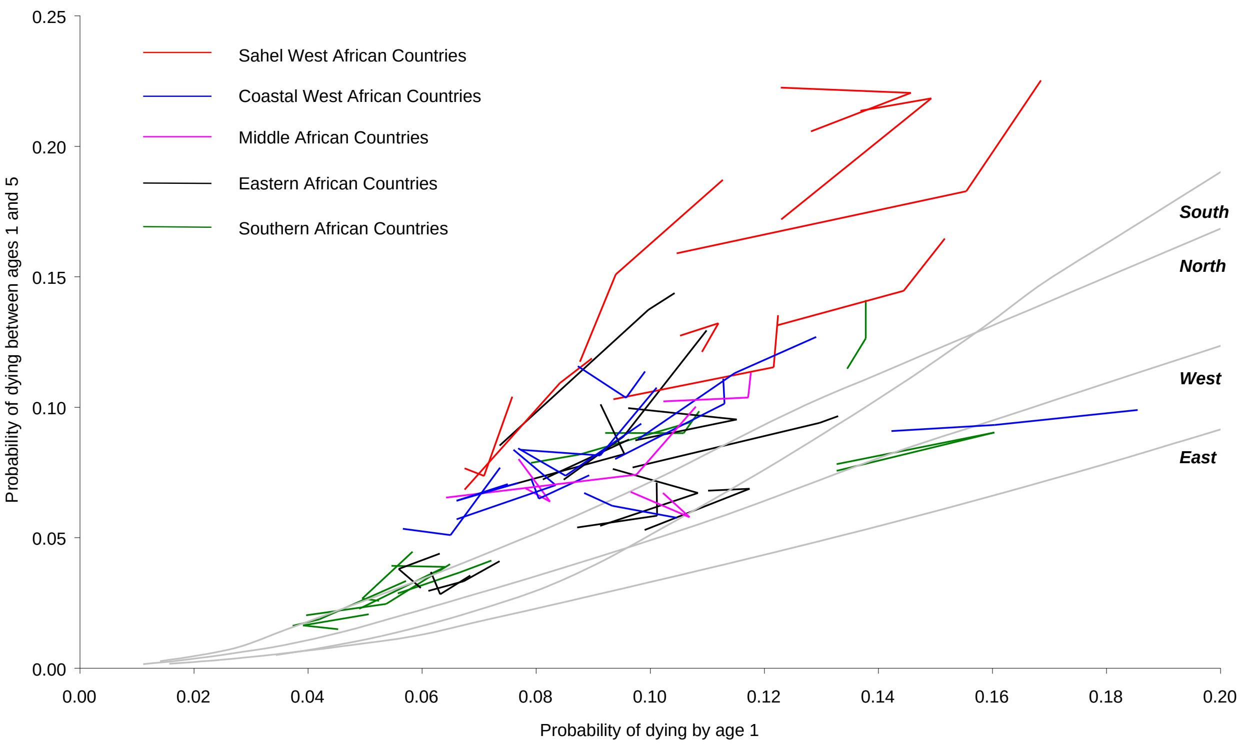



**Figure 5.5:** ***Observed childhood mortality patterns among the selected national populations in Sub-Saharan Africa, 1971 and 1998***

***Sources: Central Statistics Office [Botswana] and Macro International (1989) for Botswana; National Statistics Office [Eritrea] and Macro International (1997) for Eritrea; others computed from respective National DHS datasets.***

to-child mortality relationship points from an undefined and unknown system of model life tables. These two paths are respectively characterised by national childhood mortality patterns that:

a. Display extremely high ${}_4q_1$ for given levels of ${}_1q_0$; and

b. Track the Princeton "North" pattern at slightly higher ${}_4q_1$ relative to ${}_1q_0$.

In the first undefined pattern falls the data from all three Senegalese datasets, the Nigerien datasets, and the Malian DHS1, Nigerian DHS2 and Burundian DHS1 datasets. The remaining 21 datasets out of a total of 29 that depict patterns of higher ${}_4q_1$ relative to ${}_1q_0$ fall in the second undefined pattern of mortality in childhood. The points estimated from all these datasets cluster at ${}_1q_0$ levels of 60 to 140 per 1,000 with corresponding ${}_4q_1$ levels of about 50 to 150 per 1,000, thus tracing the Princeton "North" pattern at slightly higher levels of ${}_4q_1$.

### *5.3.2 Sub-National Childhood Mortality Patterns*

As intimated earlier, national populations are made up of sub-national populations with different socio-cultural characteristics and traditional practices, living in environments of varying hostility to the sustenance of human life. Also, human behaviour is much too complex to be contained within imaginary international boundaries. It is therefore reasonable to suggest that a closer look at childhood mortality patterns in populations residing in smaller geographical units, such as the administrative divisions of a country, may reveal differences between regions of the same country, or similarities between regions of neighbouring countries. This stage of the analysis considers a total of 165 such regions from 26 Sub-Saharan African countries, with two other countries — Eritrea and Botswana — included in their entirety because of lack of access to their respective regionally disaggregated data. Rwanda and Burundi are also considered in their entirety despite having access to their respective regionally disaggregated data because of their relatively small geographic sizes.

The same procedure of pattern identification as in the case of national populations was adopted, using data from all phases of the DHS programme. All the resulting infant-to-child mortality relationship points are juxtaposed on the patterns of the Princeton model families for comparison purposes, as well as to ease the selection of the pattern that best describes those observed in each of the 165 defined geographic units. However, it was observed in a few instances that there were no deaths between the exact ages 1 and 5 for either one or two of the three quinquennia prior to their respective surveys. Among the cases where there was complete information for two 5-year periods, the determination of the pattern that prevailed in the sub-national region is based entirely on the two child-to-infant mortality relationship points depicted by those two periods. And in instances where only one period had complete information, the pattern of mortality closest to that single point is selected as the one that prevailed in that region. The outcome is as presented in Figure 5.6.

In addition to having similar features as the outcome with respect to national childhood mortality patterns (refer to Figure 5.5), the graph reveals three issues of paramount importance and relevance to the subject matter. First, the distribution of observed patterns of mortality indicates that some regions manifest patterns such as the Princeton "East" even though none of the countries considered displayed such a pattern. Although only a few such cases exist, they represent preliminary evidence that mortality patterns in childhood do vary

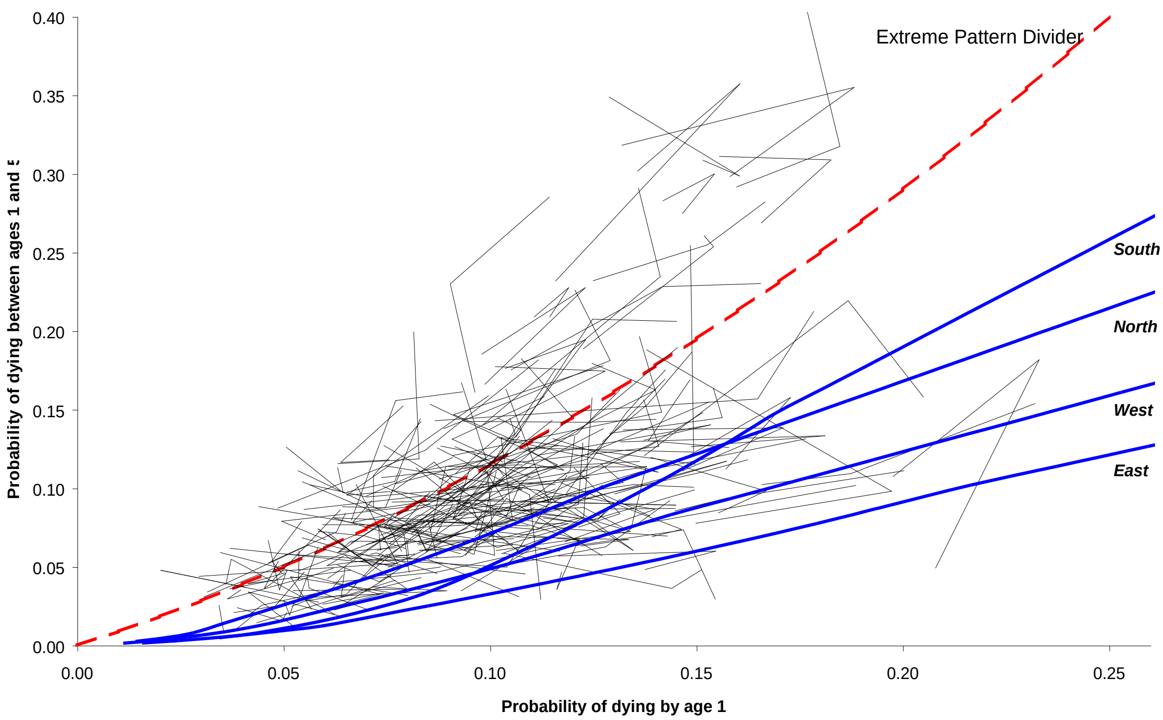



**Figure 5.6:** ***Observed sub-national regional childhood mortality patterns in Sub-Saharan Africa***

***Sources: Computed from respective National DHS datasets.***

between regions of the same country to the extent that normal patterns in some regions become masked at the national level by the extreme nature of the patterns in other regions. Secondly, more than three-quarters of sub-national regions in the Sub-Saharan African countries considered in this study experience childhood mortality patterns that cannot be described by the widely used Princeton model system of life tables. They are generally characterised by higher child mortality relative to infant, with the majority tracking the Princeton "North" model family at higher levels of child mortality. Finally, and as was observed in the case of national childhood mortality patterns, Figure 5.6 shows that sub-national regions with patterns outside the Princeton range again trace out two distinct patterns of mortality in childhood — one unusual pattern of extremely high ${}_4q_1$ for given levels of ${}_1q_0$, and another of slightly higher ${}_4q_1$ relative to ${}_1q_0$ when compared with the "North" pattern. For ease of presentation in the ensuing sections of this chapter, these unusual and undefined patterns of mortality will be referred to as:

a. ***"Sahelian Pattern"*** for instances where extremely high ${}_4q_1$ levels are displayed for given levels of ${}_1q_0$; and

b. ***"North Plus Pattern"*** for cases that track the Princeton "North" pattern at slightly higher ${}_4q_1$ relative to ${}_1q_0$.

Distinguishing between these two patterns and classifying sub-national regions accordingly is facilitated by an imaginary divider (indicated by the red broken line in Figure 5.6). This divider has no theoretical or demographic significance, and serves merely as a classificatory guide. It is based on the assumption at one end that at an infant mortality level of 50 per 1,000 live births, a corresponding child mortality level outside the range of the Princeton families will be considered extreme if in excess of 50 per 1,000; and similarly at the other end for ${}_1q_0$ of 250 per 1,000 and corresponding ${}_4q_1$ of 400 per 1,000. A simple quadratic equation passing through the origin and joining these two child-to-infant mortality relationship points is given by

$$y = 3x^2 + 0.85x,$$

where $x$ represents ${}_1q_0$, and $y$ ${}_4q_1$. Thus points falling above this line are classified as *"Sahelian"*, whilst those below it but outside the Princeton range are classified as *"North*

*Plus".* The resulting two broadly defined unusual patterns, together with the four Princeton families of childhood mortality patterns, are used to classify the patterns depicted in all 160 sub-national regions, together with Eritrea and Botswana in their entirety.

The best way of presenting the outcome for all sub-national regions is by mapping out their respective patterns accordingly, thereby revealing the geographical distribution of childhood mortality patterns across the continent. This is attempted and presented in the next section. It is preceded by an assessment of the reliability of the observed sub-national patterns of childhood mortality. This is pursued through the comparison of the outcomes for a selected number of regions with longitudinal data collected in Demographic Surveillance Sites within the selected regions.

*Validation of Observed Regional Patterns Using Longitudinal Data*

The verification of observed patterns of mortality in childhood in a selection of sub-national regions is undertaken using published longitudinal data collected from eight Demographic Surveillance sites under the INDEPTH Programme (INDEPTH Network, 2002). These sites are Niakhar, Bandafassi and Mlomp in Central, NorthEast and Southern Senegal respectively; Oubritenga and Nouna in Central/South and Eastern Burkina Faso respectively; Navrongo in Ghana Upper East Region; Gwembe in the Southern Region of Zambia; and Manhica in Maputo, southern Mozambique. The data collection procedure in each of these sites involved a baseline census followed by updates of vital events through regular visits to all households under surveillance. The intervals between these updates vary from one site to another. Details for each are discussed in INDEPTH Network (2002).

Infant-to-child mortality relationship points derived for males and females from the data from the respective surveillance sites are compared with those obtained for the sub-national regions in which the sites are located using all DHS datasets available for the countries concerned. The results are presented in Figure 5.7. It is worth pointing out that, since these sites represent only one community among many that collectively constitute their respective sub-national regions of location, the patterns of childhood mortality they depict should not be expected to

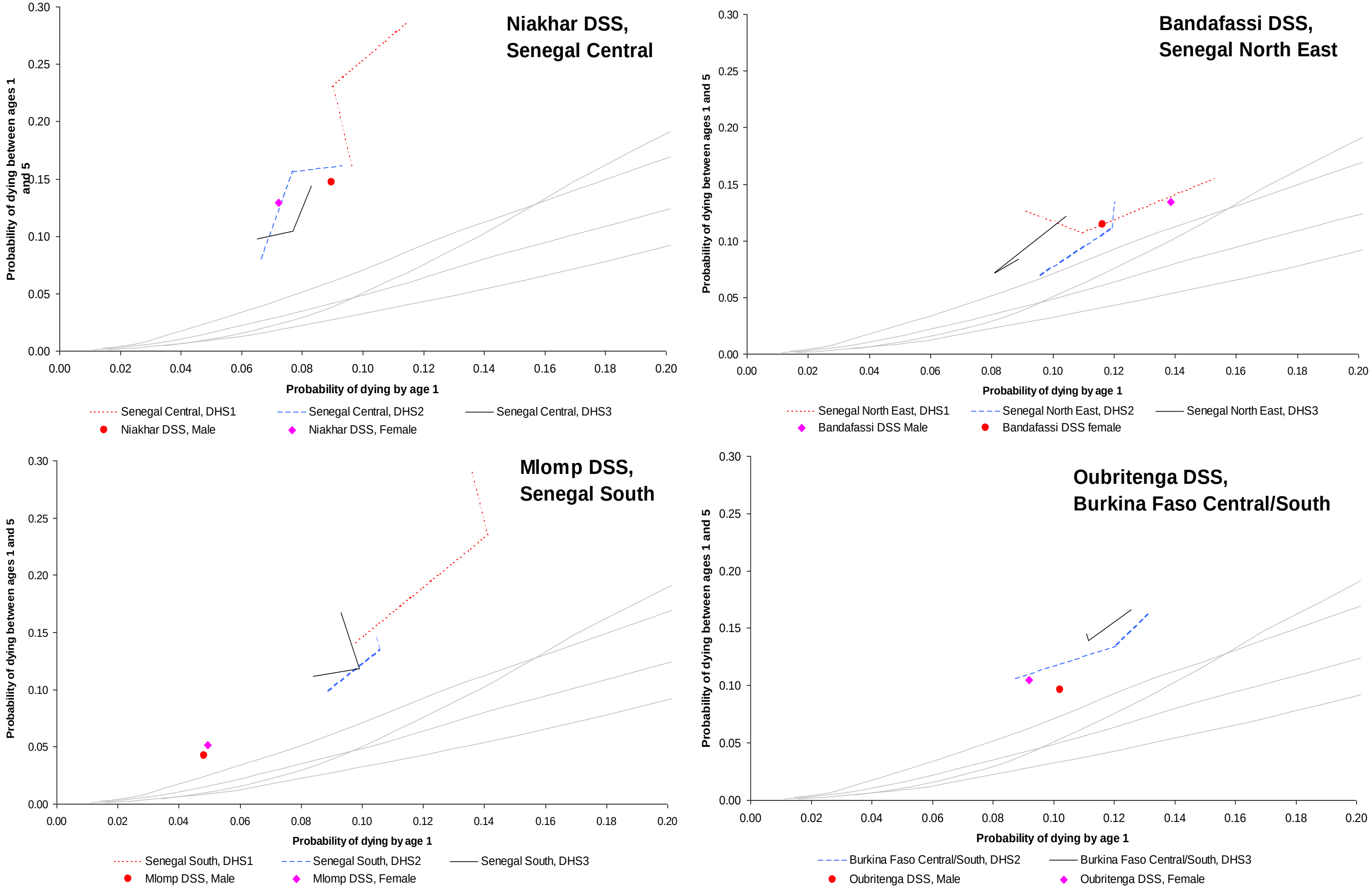
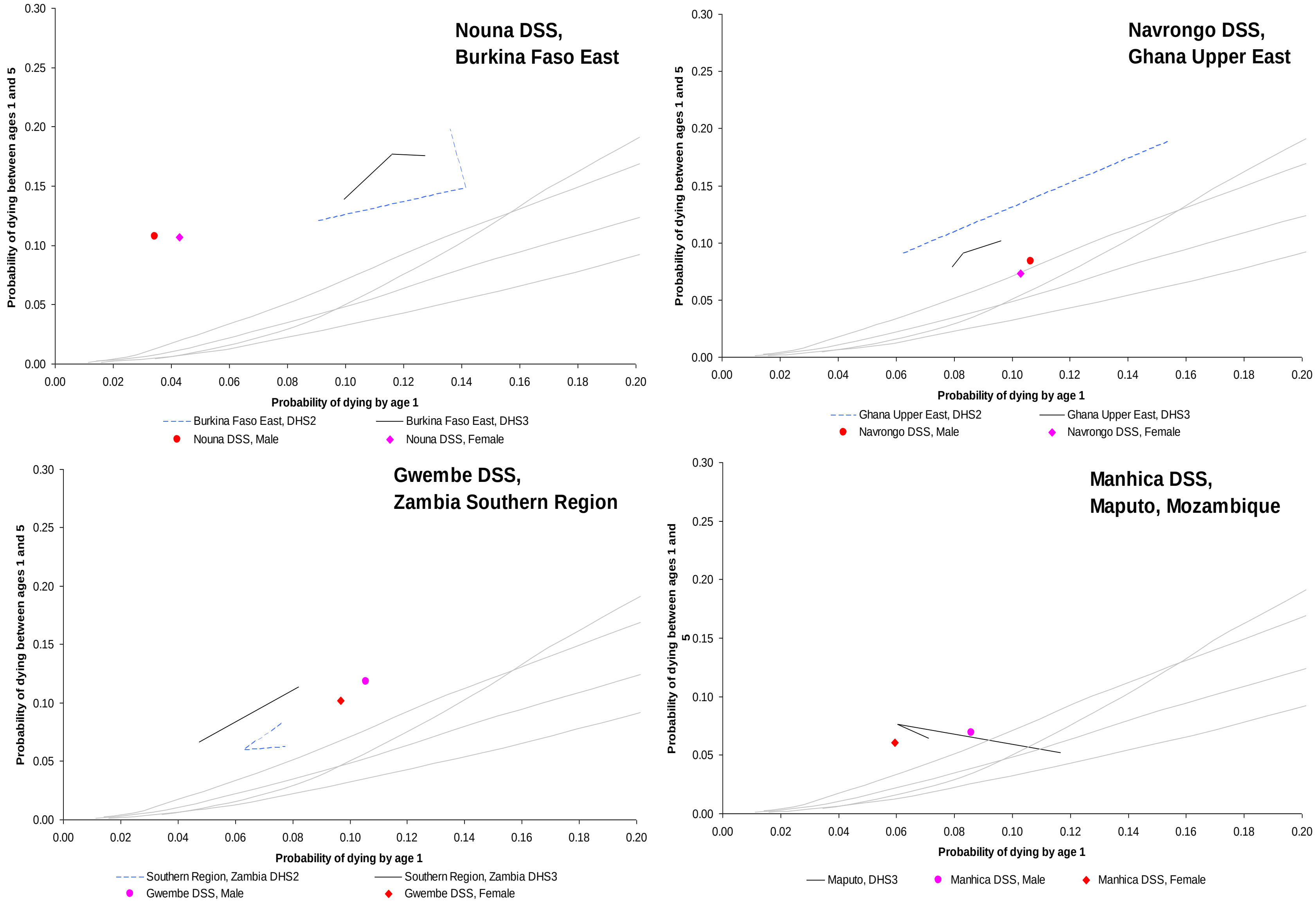



**Figure 5.7:** ***Comparison of childhood mortality patterns depicted at Demographic Surveillance Sites against those of the sub-national regions in which they are located.***

***Sources: INDEPTH Network (2002) and National DHS datasets.***

**Figure 5.7 — *continued*.**



be exactly the same as those of their regions as a whole. However, similarity between the two sets of depicted pattern irrespective of level of mortality also tends to attest to the reliability of the birth histories contained in the national DHS datasets.

In the cases of Niakhar and Bandafassi in Senegal, the infant-to-child mortality relationship points obtained for males and females from the DSS data almost perfectly match the patterns displayed at the level of their respective sub-national regions — i.e. Central and North East Senegal. The Niakhar points clearly reflect the *"Sahelian"* Pattern of childhood mortality characteristic of Central Senegal according to all three Senegalese DHS datasets. The Bandafassi points similarly portray the *"North Plus"* Pattern prevalent in North Eastern Senegal. Both sites also exhibit the prevalent levels of childhood mortality in the surrounding sub-national region.

In the case of the third Senegalese region considered, i.e. Mlomp in the south, it can be seen in the bottom left panel of the first set of graphs in Figure 5.7 that the community's longitudinal data manifests a pattern similar to that obtained from the DHS datasets for Senegal South Region is displayed, albeit at a much lower level of mortality for both males and females. The site, despite its low level of overall childhood mortality, reflects the extremely high child relative to infant mortality typical in this part of the continent.

The two sites in Burkina Faso present contrasting situations. Whilst the mortality estimates for Oubritenga display a pattern of mortality that matches those obtained from the birth histories of the respective DHS datasets for Burkina Faso Central/South, those from the site of Nouna collectively display a completely different level and pattern of childhood mortality from what birth histories indicate for the region. DHS data in Burkina Faso East reports a higher ${}_1q_0$ than the longitudinal data indicates for Nouna. Thus, the DHS survey is unlikely to have been affected by omission of infant deaths, especially in the neonatal period. In neighbouring Ghana, the Navrongo DSS in the Upper East Region manifests the Princeton “North” pattern of childhood mortality for both sexes, less extreme than the pattern prevailing in the entire region. However, the levels of ${}_5q_0$ indicated by both sources are reasonably similar. The Gwembe site in southern Zambia displays a pattern of mortality for both sexes similar to that derived for Zambia Southern Region from the second phase DHS survey. The third phase survey shows a more extreme pattern for the region. However, unlike the case of the Nouna in Burkina Faso, the Gwembe site reports higher infant mortality than both Zambia DHS surveys do for the Southern Region. This implies that either Gwembe is characterised by infant mortality higher than the average for the sub-national region in which it is located, or that both DHS surveys are affected by omission of neonatal deaths. The site of Manhica in Maputo did not yield a pattern significantly different from what the only Mozambican DHS portrays for the region despite reasonably different levels of under-5 mortality between the sexes.

Generally, therefore, the longitudinal data obtained from the eight Demographic Surveillance Sites do not yield any evidence of inaccuracies in the birth histories contained in the respective national DHS datasets. Having noted earlier that the characteristics of a site may not necessarily be the same as those of the sub-national region in which it is located, the case of the Gwembe site in Zambia should not be regarded as sufficient reason to question the validity of birth histories in both national DHS datasets relating to the Southern Region of Zambia. The validations also suggest that the birth histories constitute a reliable source of data for the investigation of both levels and patterns of mortality in childhood at the sub-national region of any country.

### *5.3.3 Changes in Observed Childhood Mortality Patterns Over Time: Country Examples*

One of the main research questions that this study aims to address is whether there is sufficient evidence to suggest that childhood mortality patterns in Sub-Saharan Africa change with overall mortality. It has already been established that overall childhood mortality levels have been changed. Whilst some countries registered recent significant declines, others experienced worrying increases. The question, therefore, is whether observed mortality patterns based on the distribution of child to infant mortality relationships change as under-5 mortality decreases, increases or remains constant? Consideration of all three quinquennia per dataset for each sub-national region can indicate whether the pattern of mortality has changed over the 15-year period that the points refer to. The same classificatory criteria are used as in the case of the national patterns.

A clear demonstration of the impact of changing mortality levels on pattern can only be achieved for countries with more than one DHS dataset. A selection of three countries is made for this purpose, with each depicting a different situation. These countries are:

i. Ghana, a case of relatively high under-5 morality, which declines rapidly over time.
ii. Kenya, a situation of low under-5 mortality but with a recent rapid increase.
iii. Zambia, a country with high and slowly increasing under-5 mortality.

As would be expected, a change in pattern becomes apparent only if very disproportionate increases or decreases are observed in ${}_1q_0$ and ${}_4q_1$ levels between consecutive surveys.

### *Ghana*

Recall from section 4.3 that 3 datasets indicate that Ghana has had a continuously declining level of childhood mortality spanning the period 1985 to 1996 (refer to Table 4.2). This general decline is reflected in both infant and child mortality levels, although child mortality dropped by about 6% between the second and third surveys compared with 32% between the first and the second. Infant mortality, on the other hand, fell by 14% in both instances. Notwithstanding this, all three datasets revealed the unusual pattern of higher child mortality relative to infant — the *"North Plus"* pattern to be precise — thus falling outside the range of the Princeton families (Figure 5.2).

The sub-regional level reveals some interesting differences. Although most of the sub-national regions reflect the unusual pattern of childhood mortality prevailing at the national level — as shown in the map relating to DHS1 in Figure 5.8 — the Central Region in the south is characterised by the Princeton “South” pattern of childhood mortality. The northern parts of the country (i.e. the Northern, Upper West and Upper East regions grouped into one sub-national region in the first phase survey), as well as the Greater Accra, Eastern and Ashanti Regions of southern Ghana, show the *"Sahelian"* pattern.

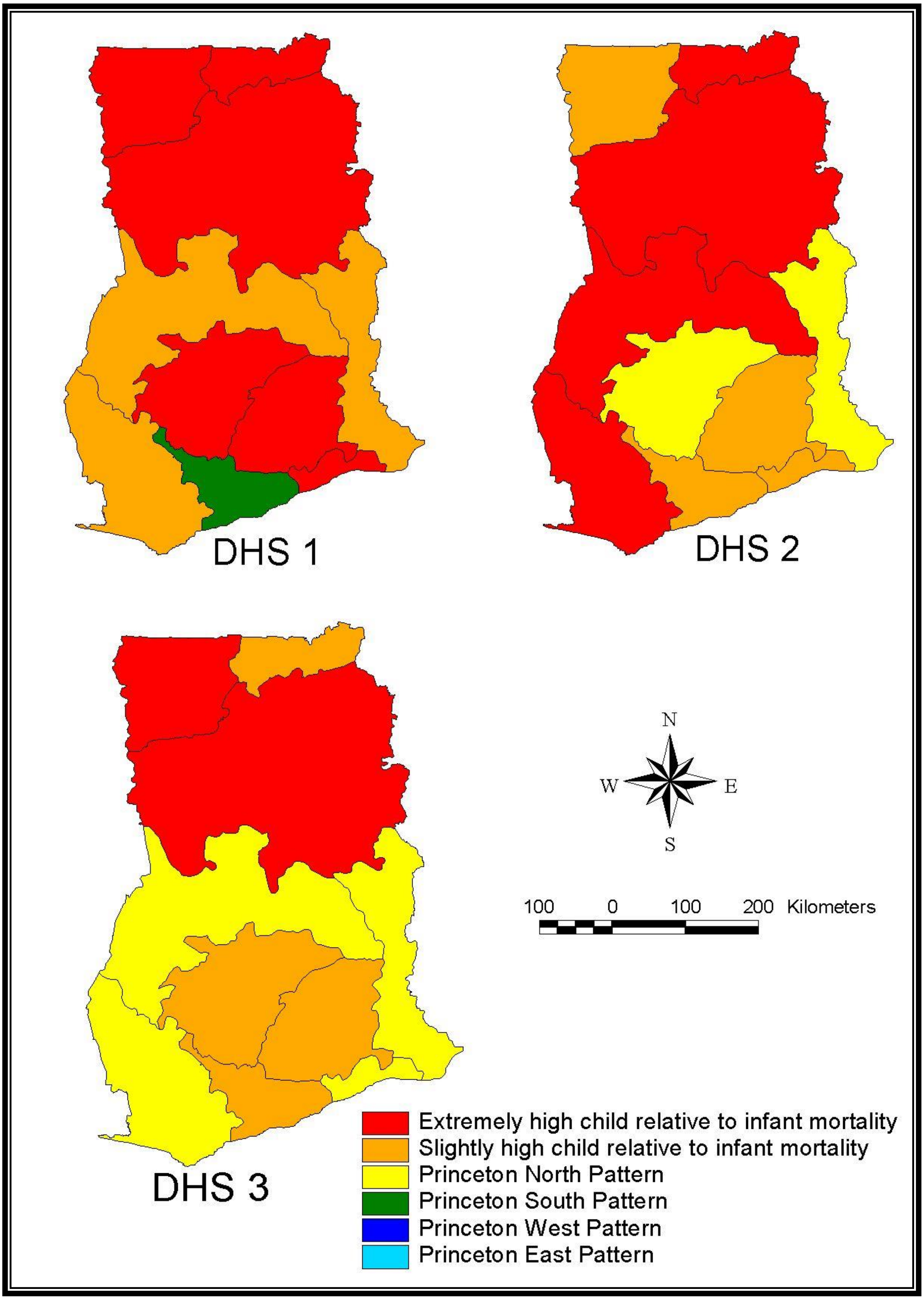



**Figure 5.8:** ***Changes in regional childhood mortality patterns by DHS Phase in Ghana.***

A comparison of regional mortality indicators between the first and second survey phases shows a general decline in overall childhood mortality as well as in ${}_1q_0$ and ${}_4q_1$ in all regions but two. Western Region registered an increase in ${}_4q_1$ despite a decrease in ${}_5q_0$, whilst Greater Accra had an increase in both ${}_5q_0$ and ${}_1q_0$, but a corresponding decrease in ${}_4q_1$. The resulting relationships between infant and child mortality imply pattern changes in four-fifths of the regions. The Northern and Upper East regions are the only sub-national geographical units that maintained the *"Sahelian"* pattern they manifested in the earlier survey. All other regions in the southern half of the country displayed childhood mortality patterns different from those that prevailed in the first phase survey, the most significant being the transformation of the Central Region from a Princeton "South" pattern to the moderate form of the unusual pattern. The Western and Brong Ahafo regions had their childhood mortality patterns transformed from the *"North Plus"* to the *"Sahelian"* form, whilst those of the Eastern and Greater Accra regions changed from the *"Sahelian"* to the *"North Plus"* form. Ashanti and Volta Regions display transformations from the *"Sahelian"* and the *"North Plus"* patterns respectively to the Princeton "North" pattern. As the Central Region's *"North Plus"* pattern is surrounded by regions with similar patterns, the Princeton "South" pattern depicted by the first phase survey can probably be attributed to data error.

The overall 6% decline in national ${}_5q_0$ between the second and third surveys is reflected differently among the sub-national regions, especially in terms of ${}_1q_0$ and ${}_4q_1$. Only Central and Upper East Regions registered increases in ${}_5q_0$, and it was only in the former that this increase was due to rises in both ${}_1q_0$ and ${}_4q_1$. It was due to an increase in ${}_1q_0$ in the latter. Despite decreases in overall under-5 mortality in all the other eight Ghanaian sub-national regions, four such decreases — i.e. in the cases of Eastern, Ashanti, Volta and Upper West Regions — were underlain by increases in ${}_4q_1$ and, of course, corresponding significant falls in ${}_1q_0$. Whilst the decrease in ${}_5q_0$ in Brong Ahafo was accounted for by a significant decrease in ${}_4q_1$ overshadowing an increase in ${}_1q_0$, those observed in Greater Accra, Western and Northern Regions resulted from falls in both ${}_1q_0$ and ${}_4q_1$.

The infant-to-child mortality relationships that emerged from third national survey are shown in terms of the childhood mortality patterns they depict in the map associated with DHS 4 in Figure 5.8. Four regions maintained the same pattern of mortality they displayed at the second survey. These are the *"Sahelian"* Pattern in Northern Region, the Princeton "North" Pattern in

Volta Region, and the *"North Plus"* Pattern in Central and Eastern Regions. However, the Upper West Region reverted back to the *"Sahelian"* Pattern of childhood mortality as a result of an increase in ${}_4q_1$; whilst that of the Upper East Region changed from the *"Sahelian"* to the *"North Plus"* Pattern because of an increase in ${}_5q_0$ brought about by a significant rise in ${}_1q_0$. Brong Ahafo, Western and Greater Accra Regions had unusual patterns at the second survey transformed to the Princeton "North" Pattern. All the transformations to the Princeton "North" Pattern were associated with declines in ${}_5q_0$ to levels less than 120 per 1,000 and an associated decline in ${}_4q_1$. Despite registering declines in both ${}_5q_0$ and ${}_4q_1$, the Northern Region manifested under-5 mortality levels in excess of 175 per 1,000 throughout the period covered by all three national surveys, and maintained the *"Sahelian"* Pattern throughout.

These changes in pattern of mortality in childhood suggest that as ${}_5q_0$ levels declined over the period covered by all three surveys, the southern half of Ghana had gradually developed a Princeton "North" type pattern of childhood mortality, despite the prevalence of slightly higher child mortality relative to infant in Central Eastern and Ashanti Regions. The extreme form of the unusual pattern has become confined to the Upper West and Northern Regions, which has relatively high levels of ${}_5q_0$ over the period.

*Kenya*

Unlike Ghana, Kenya — at relatively lower levels of under-5 mortality — has consistently had a national childhood mortality pattern within the range of the Princeton model system throughout its three national surveys. This is the Princeton "North" pattern in the case of the first survey, and somewhere between Princeton "North" and "West" patterns for the second and third surveys. Although Ghana maintained a consistent decline in ${}_5q_0$ at the national level throughout its three surveys, the situation in Kenya is characterised by a recent increase in ${}_5q_0$. With a national under-5 mortality rate of about 89 per 1,000 in the five-year period prior to its first survey, sub-national levels for the same period ranged from a relatively low level of 45 per 1,000 in Central and Rift Valley Regions to an extremely high level of more than 140 per 1,000 in Nyanza and Western Regions.

The Princeton "North" Pattern of childhood mortality depicted at the national level by the first phase survey is underlain by four different patterns at the regional level as shown by the map associated with DHS 1 in Figure 5.9. These are the Princeton "West" Pattern in Central and Rift Valley regions, the "North" Pattern in Nyanza and Eastern Regions, the "South" Pattern in Coast Region, and the *"North Plus"* Pattern in Western Region and Nairobi. With the majority of the regions displaying Princeton type patterns, the distribution of regional childhood mortality patterns on the basis of the first surveys appears plausible.

The first two Kenyan surveys were conducted during a period characterised by a gloomy economic situation and the emergence of the direct and indirect effects of the AIDS epidemic on the morbidity and mortality of parents and young children. Thus, the regions of Kenya manifested different changes in ${}_1q_0$ and ${}_4q_1$ levels between these two surveys. Comparing the first quinquennia before each survey, an increase in ${}_5q_0$ was registered in four out of Kenya's seven sub-national regions, viz.: Eastern, Nairobi, Rift Valley and Nyanza Regions. These increases were due to rises in both ${}_1q_0$ and ${}_4q_1$ except in Nairobi, where it was due to an upsurge in child mortality. Coast and Nairobi Regions registered falls in ${}_5q_0$ despite accompanying slight increases in ${}_4q_1$; and both ${}_1q_0$ and ${}_4q_1$ dropped between the two surveys in Central and Western Regions. The accompanying childhood mortality patterns reflecting these changes are shown by the map associated with DHS 2 in Figure 5.9. Both Nairobi and Western Regions maintained the *"North Plus"* Pattern despite one having registered an increase in ${}_5q_0$ and the other a decrease. Rift Valley Region also maintained the Princeton "West" Pattern despite registering increases in both ${}_1q_0$ and ${}_4q_1$. Whilst significant falls in ${}_1q_0$ relative to ${}_4q_1$ modified the childhood mortality patterns in Nyanza and Eastern Regions from Princeton "North" to "West", the Central Region changed from "West" to "North". Coast Region had its pattern shift from "South" to "North" due to an increase in ${}_4q_1$. With the data from the second Kenyan survey depicting a national childhood mortality pattern that hovers somewhere between "North" and "West", the distribution of regional patterns shown suggests nothing different.

A Similar comparison of the third and second phase surveys reveals increases in ${}_5q_0$ in all regions except for Nairobi and Central Regions. Rises in ${}_1q_0$ only were responsible for the increases in Coast, Eastern and Rift Valley Regions. Increases in ${}_4q_1$ contributed to the under-

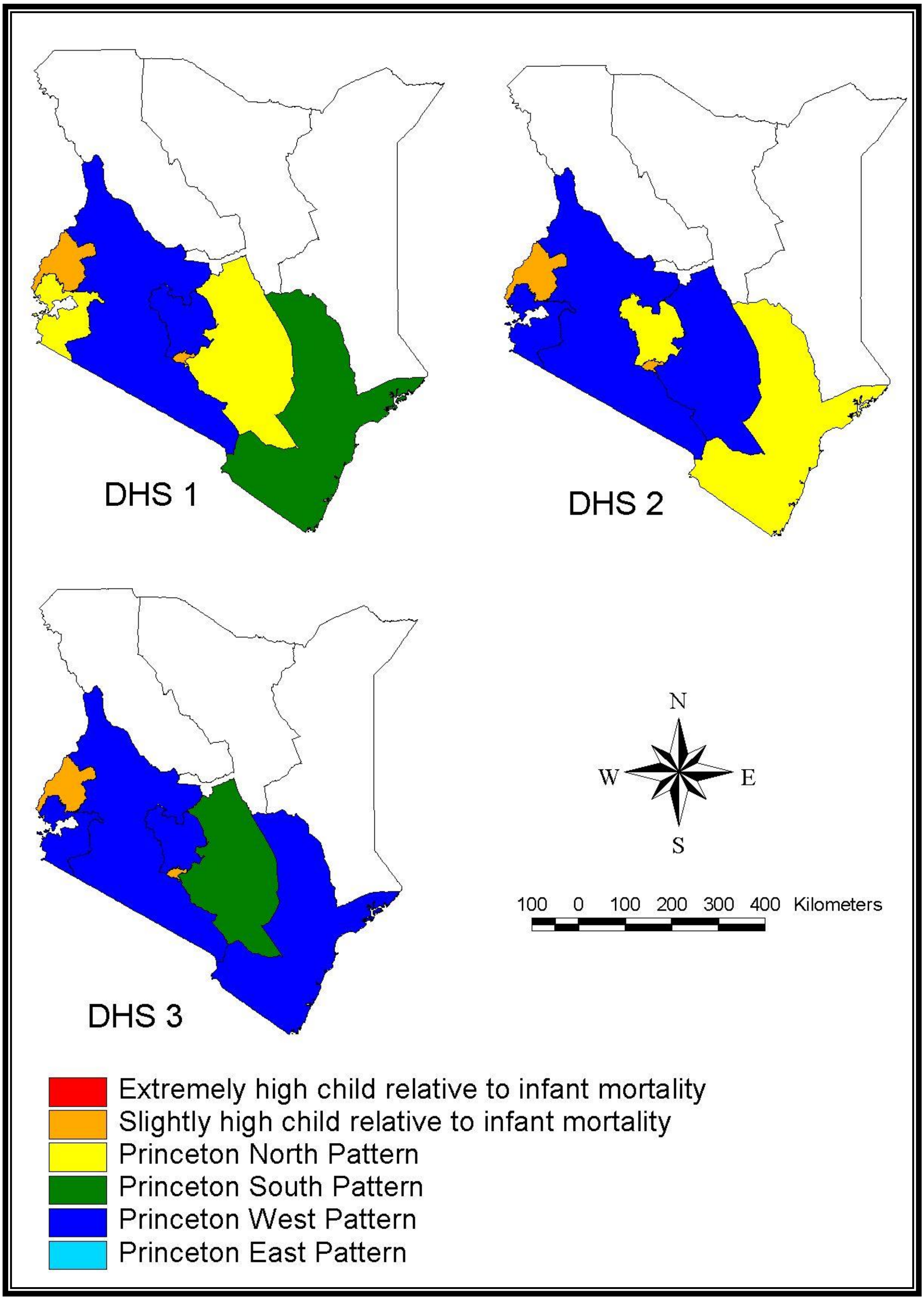



**Figure 5.9:** ***Changes in regional childhood mortality patterns by DHS Phase in Kenya.***

five mortality increase in Nyanza and Western Regions. These variations mean that the Princeton "West" Pattern of childhood mortality has become the most prevalent in Kenya, covering Nyanza, Rift Valley, Central and Coast Regions. The Eastern Region's pattern shifted from "West" to "South" due to the observed increase in ${}_1q_0$. Nairobi and Western Regions maintained the *"North Plus"* Pattern despite an increase in both ${}_1q_0$ and ${}_4q_1$ in the case of Western Region.

The case of Kenya demonstrates various situations that can arise in relation to the dynamics of childhood mortality patterns at low but increasing levels of under-5 mortality. Unlike Ghana, where declines in sub-national ${}_5q_0$ levels resulting from relatively steeper falls in ${}_4q_1$ were driving prevailing patterns towards the Princeton "North", recent increases in ${}_5q_0$ in Kenya's sub-regions result mainly from rises in infant mortality and are bringing about convergence of most regional childhood morality patterns to those in the Princeton "West" models.

*Zambia*

Zambia has high childhood mortality levels by African standards with evidence of a slight increase between its two Demographic and Health Surveys — 3% based on comparison of first quinquennia prior to each survey. The economic and epidemiological circumstances that prevailed in the country during this period were similar those that obtained in Kenya. The 3% increase in ${}_5q_0$ was as a result of a 1% and 4% rise in infant and child mortality levels. As shown in Figure 5.4, data from both surveys indicate the prevalence of the *"North Plus"* Pattern of childhood mortality at the national level.

At the sub-national regional level, the second phase Zambian survey (i.e. the country's first DHS) showed that under-5 mortality rates range from a little under 160 per 1,000 in the Southern Region to about 300 per 1,000 in Luapula. The make-up of these levels of ${}_5q_0$ in terms of ${}_1q_0$ and ${}_4q_1$ reveal a distribution of four different patterns of childhood mortality as depicted by the upper map in Figure 5.10, two of which are of the unusual types with high child relative to infant mortality. The *"North Plus"* Pattern prevailed in the southern and eastern parts of the country covering the Northern, Eastern, Central, Southern and Lusaka

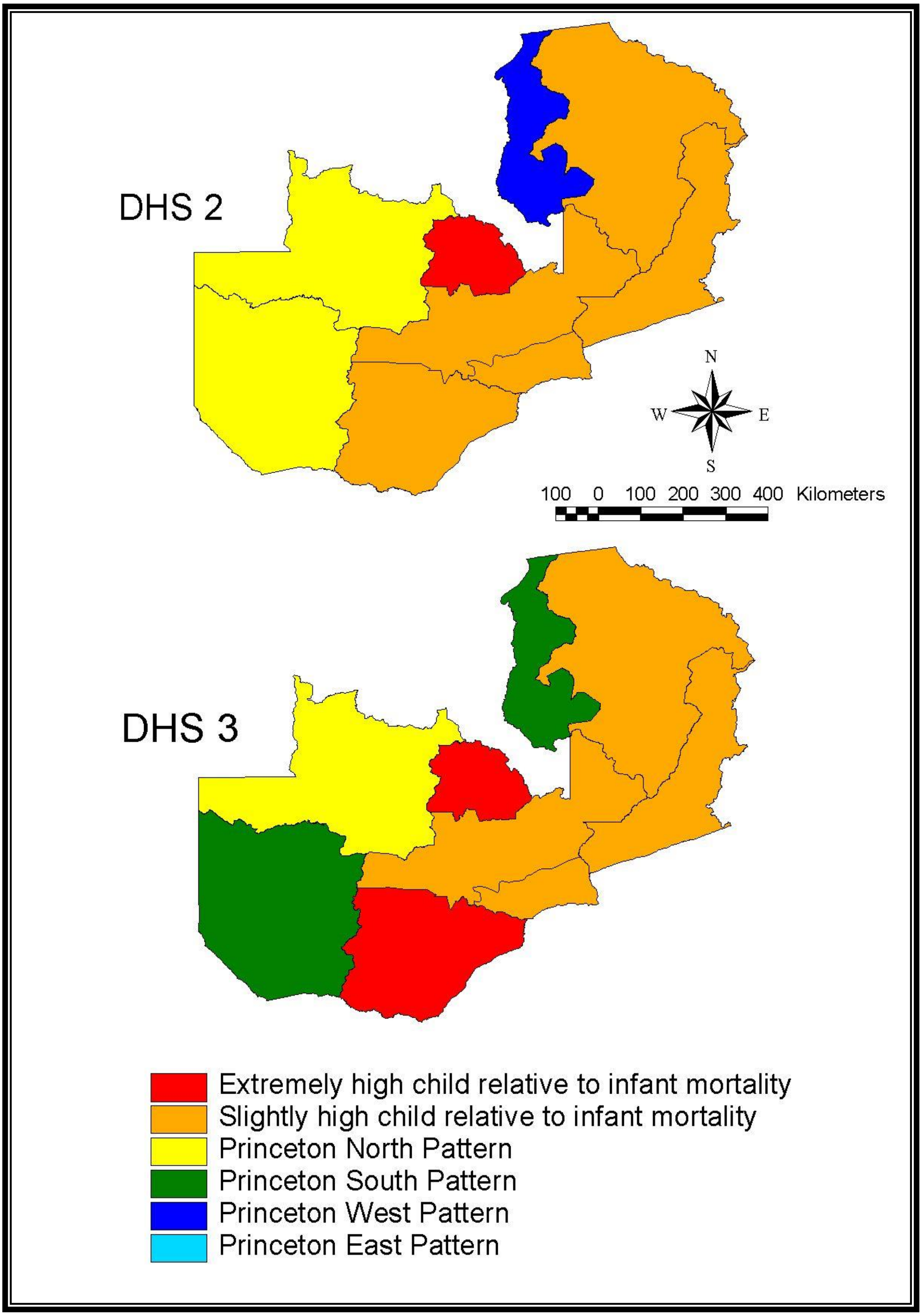



**Figure 5.10:** ***Changes in regional childhood mortality patterns by DHS Phase in Zambia.***

Regions; whilst the Copperbelt Region in the centre, which is densely populated and relatively highly urbanised, showed the *"Sahelian"* Pattern. The Princeton "North" pattern was prevalent in the entire western part of the country — i.e. the Western and North-Western Regions; and the northern region of Luapula displayed the "West" Pattern at a relatively high level of ${}_5q_0$.

Comparing indicators relating to the quinquennium prior to the two surveys, increases in ${}_5q_0$ were observed in Central, Copperbelt, Lusaka and Southern Regions. The decrease in Luapula was accompanied by a rise in ${}_4q_1$; whilst that in the North-Western Region occurred with an increase in ${}_1q_0$. Drops in both infant and child mortality in Western, Northern and Eastern Regions. These variations resulted in changes in observed mortality patterns in three regions. The increase in child mortality in Luapula noted above shifted the Princeton "West" pattern of child mortality to "South"; whilst the increase in infant mortality in the North-Western Region yielded a change from "North" to "South" Pattern of childhood mortality (see lower map in Figure 5.10). The increases in both ${}_1q_0$ and ${}_4q_1$ in Southern Region meant a change from the *"North Plus"* to the *"Sahelian"* Pattern. Essentially, the regions that displayed Princeton type patterns on the basis of data from the second phase survey also depict patterns within the Princeton range in the third phase survey. The situation in the regions dominated by the unusual patterns suggests that worsening under-5 mortality in Zambia has tended to shift regional childhood mortality patterns towards the *"Sahelian"* Pattern — the opposite of the situation in Ghana.

#### *5.3.4 Geographical Distribution of Most Recently Observed Childhood Mortality Patterns*

Bringing together the most recent observed patterns for all the 165 regions of the 26 countries yields the distribution shown in Figure 5.11. Since the different national surveys were conducted on different dates, caution should be exercised in the interpretation of the map in its entirety because adjacent regional patterns may relate to different time periods within the range of 1971 to 1998. Notwithstanding this, adjacent regions are unlikely to manifest significantly different patterns of mortality even if they relate to different points in time of up to 5-10 years. As a result, the map provides an opportunity to examine the types of childhood mortality patterns (on the basis of infant-to-child mortality relationships) that prevail in different parts of the continent without being constrained by international boundaries. In fact,

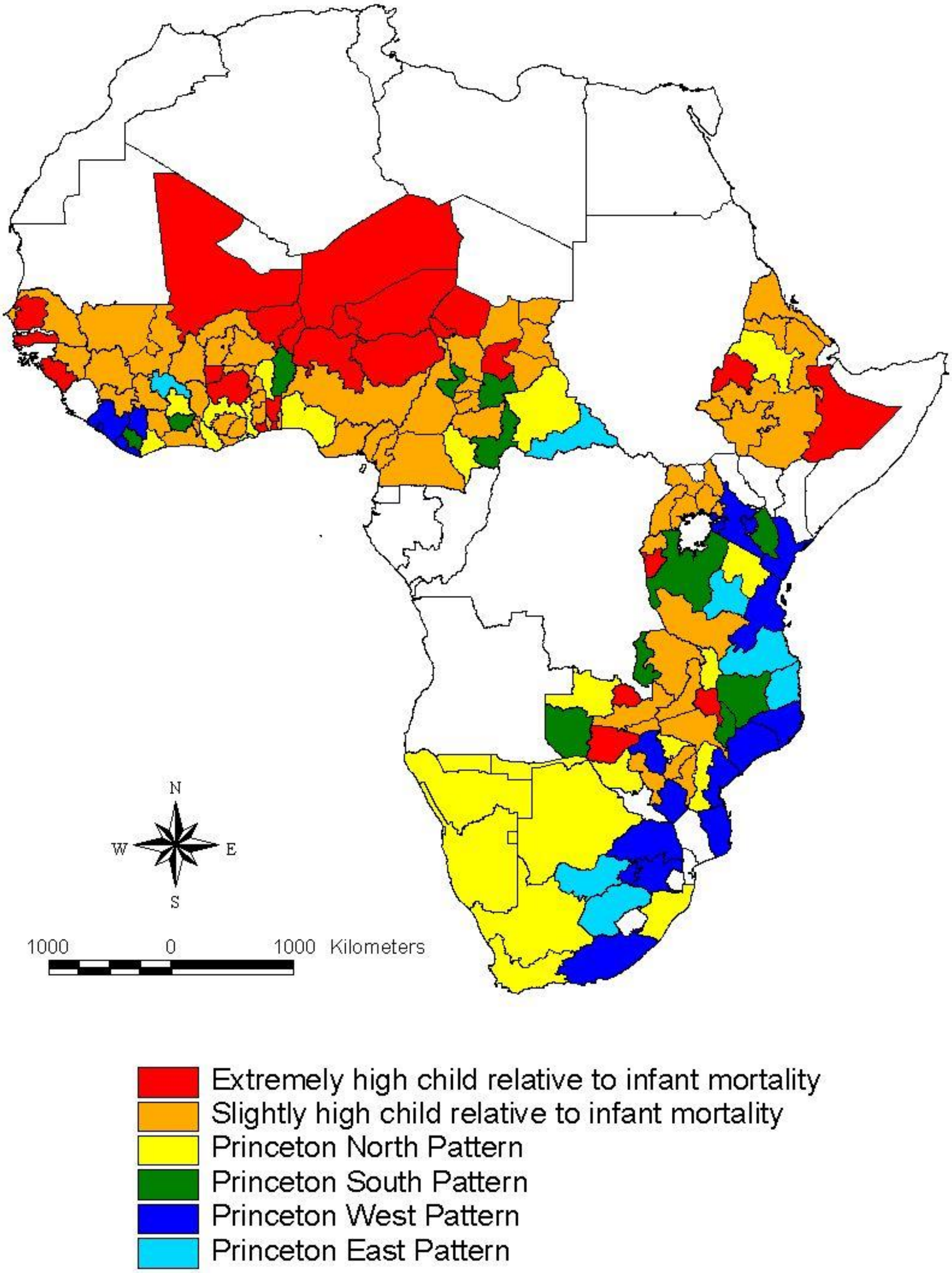



**Figure 5.11:** ***Geographical distribution of the observed childhood mortality patterns in Sub-Saharan Africa, 1971 – 1998.***

the existence in adjacent regions in different countries of similar patterns of mortality in childhood tends to confirm not only the existence of that pattern, but also the reliability of both datasets from which the relevant computations were made.

The map shows the dominance of the unusual pattern of high child mortality relative to infant mortality in West and Middle Africa. If Liberia and Mozambique are excluded, it appears that the distribution of the pattern of mortality reflects to a large extent the distribution of childhood mortality levels in the continent. Regions with low under-five mortality are more likely to display a Princeton pattern than regions with relatively higher under-five mortality. The Princeton "North" pattern is prevalent in the western half of Southern Africa, whereas the "West" and "East" patterns dominate the south-eastern part of this region. In the north-eastern part, however, Zambia manifests similar patterns as those prevalent in West Africa.

Childhood mortality patterns of more than 75% of sub-national populations in West and Central Africa cannot be represented by any of the Princeton model patterns. The same is true of about 50% of sub-national populations in Eastern and Southern Africa. Apart from Rwanda, Burundi, Eritrea and Botswana, which are considered in their entirety, only Niger, Burkina Faso, Cameroon, Uganda, and Namibia have the same childhood patterns in all sub-national regions. Central African Republic and Côte d'Ivoire display three and four Princeton mortality patterns respectively, as well as the moderate form of the unusual pattern. In Central African Republic no two neighbouring regions share the same childhood mortality pattern.

Other pertinent observations regarding the general distribution of mortality patterns in childhood are:

- The sub-national regions displaying Princeton patterns in West Africa are all in the south of that part of the region, thus suggesting a southward reduction of pattern extremity from the Sahara;

- In most cases, regions with the *"Sahelian"* pattern are bordered by at least one other adjacent region with the *"North Plus"* pattern.

- The Princeton “East” pattern found in Côte d’Ivoire North and Health Region V in the Central African Republic are bordered by very different patterns, and may result from poor quality data.

With respect to cross-country similarities in childhood mortality patterns, vast contiguous geographical entities exist that are made up of sub-national regions of different countries. Perhaps the most conspicuous case of cross-country similarities in patterns is that involving Liberia and the southwest of neighbouring Côte d’Ivoire. On the basis of the Liberian DHS 1 dataset alone, one would dismiss the depicted Princeton “West” pattern it found in a part of the continent characterised by the prevalence of more extreme patterns as a case of flawed data. However, the Ivorien third phase survey reveals that the country’s West region adjoining Liberia has a similar "West" pattern, which appears to confirm the accuracy of the Liberian data. Other instances of such cross-country similarities include the following situations:

- Northern Mali, the whole of Niger, northern Nigeria and south-western Chad have the *“Sahelian”* pattern;

- Centre-west and south-east of West and Middle Africa, which cover parts of several countries or even whole countries such as Burkina Faso in the former demarcation and Cameroon in the latter, display the *“North Plus”* pattern. The same pattern also dominates a vast area stretching from western Zimbabwe, north-western Mozambique, through central and north-eastern Zambia to the Southern Highlands of Tanzania.

- The whole of Namibia, Botswana, the western half of South Africa and western Zimbabwe share the Princeton “North” pattern. The north-eastern region of South Africa, southern Zimbabwe, and the coastal regions of Mozambique are characterised by a "West" pattern except for the region of Cabo Delagado in the north, which displays the Princeton "East" pattern matching that of Tanzania South. Further north, the Coast regions of Tanzania and Kenya also manifest the same “West” pattern of childhood mortality.

As far as time variations in childhood mortality patterns are concerned, comparisons were made between the patterns depicted by the most recent (i.e. third and fourth phase) surveys and those from earlier surveys (as shown in Figure 5.12) in a manner similar to that of the three country examples presented earlier. The following conclusions are drawn:

- The unusual pattern of extremely high ${}_4q_1$ relative to ${}_1q_0$ remains prevalent in the whole of Niger.
- The western half of Mali has evolved from the extreme to the moderate form of the unusual pattern.
- The area covering southern Ghana and Togo is developing a Princeton "North" type pattern, and the extreme form of the unusual pattern is becoming confined to the Upper East and Northern Regions of Ghana.
- The mortality patterns in Kenya's Coast and Central Regions have evolved from "South" and "North" respectively to "West".
- Regions formerly with "North" or the North Plus patterns in Zambia and Zimbabwe have changed to the moderate or extreme forms of the unusual pattern. This is linked to a rise in overall childhood mortality, which has already been discussed in Chapter 4 (Section 4.6.5).

## 5.4 Discussion

This chapter has charted the first detailed geographical description of childhood mortality patterns in Sub-Saharan Africa. Previous studies of this nature (Blacker *et al.*, 1985; Hill, 1995; Bicego and Ahmad, 1996) focused on the national level. This graphical approach to assessing childhood mortality patterns has limitations. Not only is it subjective in nature, but the fact that each infant-to-child mortality point refers to a five-year period introduces an element of rigidity to the interpretation of the resulting patterns identified. International comparisons are based on surveys that refer to slightly different time periods, and those

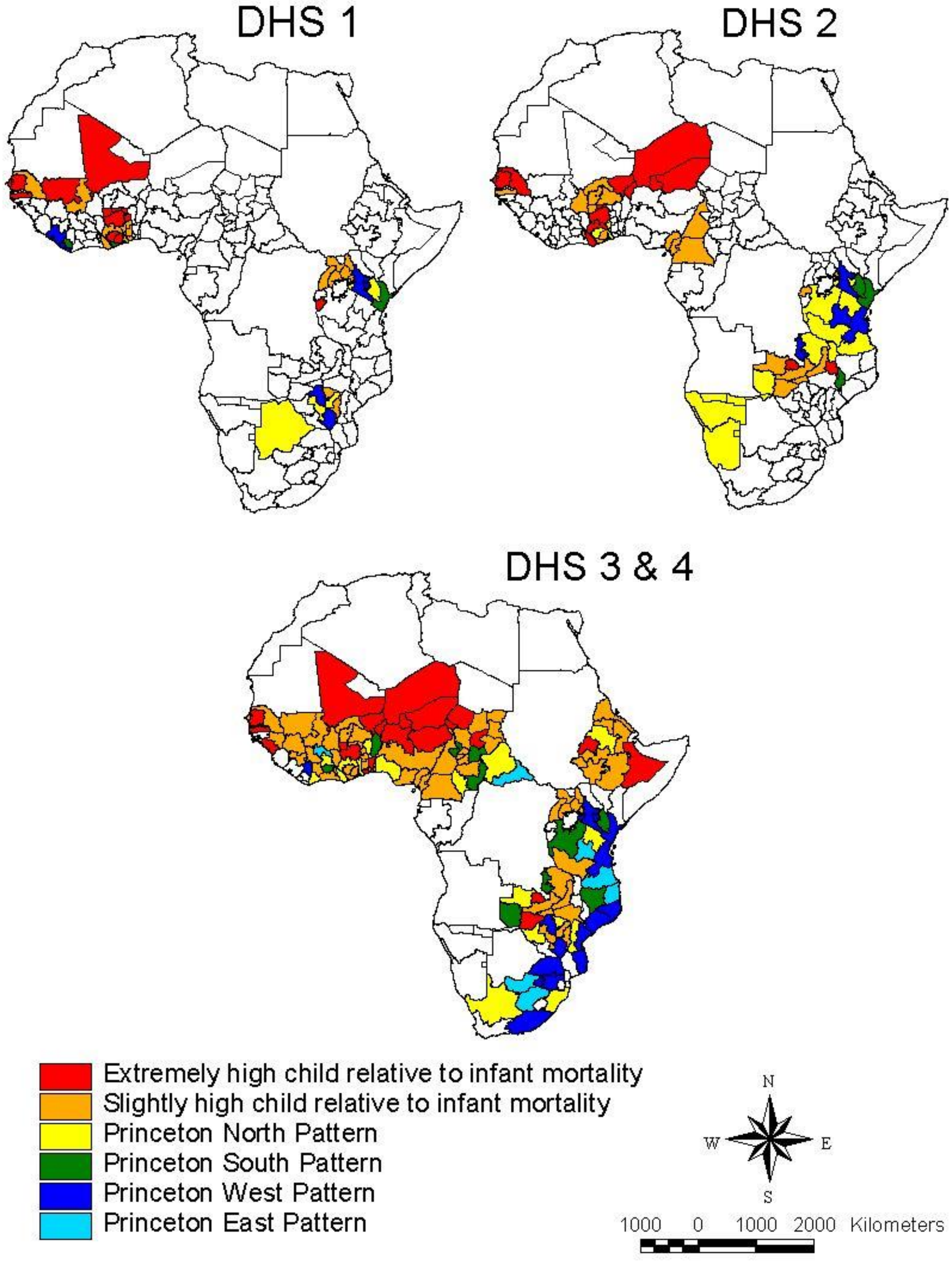



**Figure 5.12:** ***Geographical distribution of the observed childhood mortality patterns in Sub-Saharan Africa by DHS phase.***

countries whose most recent surveys are 12.5 years apart cannot have their respective patterns of childhood mortality compared over time. Also, five years constitute rather a short period for significant changes in mortality patterns to become apparent. However, the unstable economic and epidemiological conditions that have prevailed in Sub-Saharan Africa over the past three decades have resulted in rather drastic changes in mortality. Such dynamism means that the pattern of mortality of a sub-national region can change within a period of five years. Despite these limitations, the following findings have been arrived at:

- With respect to the ongoing checks on the quality of the datasets being used, the data from a number of selected Demographic Surveillance Sites have yielded no evidence of major biases in the DHS birth histories pertaining to the sub-national regions in which the respective sites are located.

- In all cases the individual surveys of the same country largely confirm each other. This is clearly demonstrated by the three country examples of Ghana, Kenya and Zambia. With the exception of the Central Region in Ghana, which manifested a Princeton "South" Pattern according to data from the first phase Ghanaian survey, there are no instances where very different patterns of mortality prevail in adjacent regions. The exception is Luapula in Zambia according to the second phase Zambian survey. However, the third survey confirms that the "West" Pattern displayed in the first instance probably does characterise the area.

- Childhood mortality patterns characteristic of all four families of the Princeton system prevail in the continent. In addition, an unusual pattern of extremely high child mortality relative to infant mortality is also observed and prevails in almost two-thirds of the sub-national regions of the 26 countries considered in the study. Particularly extreme relationships between ${}_4q_1$ and ${}_1q_0$ are most common in the Sahel.

- The Princeton patterns are more prevalent in Eastern and Southern Africa than in any other part of the continent; whilst the unusual patterns dominate much of West and Middle Africa.

- The majority of Sub-Saharan African countries do not have a regionally homogeneous pattern of mortality in childhood. As a result, national data in many cases mask the fact that either extreme or normal Princeton patterns are prevalent in some regions. Based on most recent information available, the only countries with regionally homogeneous age patterns of childhood mortality are Niger, Cameroon, Uganda, Rwanda and Namibia.

- No West African country has experienced a recent rise in under-five mortality. The change in pattern in some coastal regions over time can be linked to the decline in overall childhood mortality. The age pattern of mortality has also changed in Zambia and Zimbabwe as overall childhood mortality has increased. This essentially implies that the dynamism of the mortality situation in the continent is reflected in the prevailing mortality patterns. This is further evinced in the outcomes of the three country examples presented, thus giving strong indications of time variations in childhood mortality patterns at the sub-national level in Sub-Saharan Africa.

The evidence from Zambia and Zimbabwe suggests that much of the recent increase in childhood mortality is at ages 1 and 5. HIV sero-prevalence rates are highest in this part of the continent and the unfolding dynamics of childhood mortality patterns in these countries can be linked to the AIDS epidemic. Is it likely that as the AIDS situation worsens in Eastern and Southern Africa, the nature and distribution of childhood mortality patterns in the continental sub-regions will become more like those observed in West Africa? Whilst this remains a worrying question to ponder in relation to the methodological consequences the AIDS epidemic poses to established demographic techniques and procedures developed for and widely used in the continent, the most pressing question in the line of the current enquiry is: what is so peculiar about Sub-Saharan African mortality that the Princeton model system cannot adequately describe the childhood mortality patterns prevailing in the majority of sub-national regions of the 26 countries considered?

# Chapter 6

# Age-Specific Mortality Schedules in Childhood

## 6.1 Introduction

The preceding chapters focus on the aggregates of the two main components of childhood mortality, viz.: infant and child mortality. This constitutes a fair reflection of the status quo in demographic research as far as childhood mortality in Sub-Saharan Africa is concerned. The limitations of demographic data in the continent mean that little, if anything, has been documented on African mortality schedules within infancy or early childhood. It was shown in Chapter 5 that, on the basis of the aggregate indicators of infant and child mortality, many sub-national regions in Sub-Saharan Africa manifest childhood mortality patterns that differ from those of the Princeton families. A reasonable question to ask, therefore, is whether such a difference in patterns is due to significant differences in the overall shape of age-specific mortality schedules spanning birth and age 5 years between Sub-Saharan African populations and the historical European populations from whose life tables the Princeton model system was constructed. In other words, is there a marked difference in the structures of age-specific death rates in childhood between the two sets of populations which is affecting the relative size of infant and later childhood mortality?

Unfortunately, the detailed mortality schedule between birth and age five years — in both developed and developing countries — has not been systematically studied and documented in the demographic literature. It is justifiable, therefore, to question whether a universal shape of age-specific mortality rates within the first five years of life exists like the J-shaped pattern for all-age and AIDS-free mortality schedules. Although they are a relatively short period compared with the normal life span, the first five years of life are the most critical and arguably interesting as far as human mortality studies are concerned. It is clear that mortality in infancy and early childhood can vary independently of each other, and that they respond differently to economic and epidemiological circumstances (Reher *et al*., 1997). In addition, observations on historical European populations have shown that instances occur of contradictory swings in mortality among children at different ages. For example, child mortality may decline while ${}_1q_0$ is stable or even rising, as was the case in Spain in the first half of the nineteenth century (Reher *et al.*, 1997); and in England and Wales in the second half of the nineteenth century (Woods *et al.,* 1997). Reher *et al*. (1997) in their examination of childhood mortality patterns in Spain during the demographic transition conclude that *"…internal differences have emerged that should caution us against simple blanket explanations of childhood mortality. As a minimum, we must differentiate between infant and child mortality, since the timing and intensity of trend changes for each were quite different"*.

Each component of under-5 mortality can be sub-divided into two or more constituents. For instance, ${}_1q_0$ can be divided into neonatal mortality, ${}^{m}q_0$, i.e. the probability of dying between birth and exact age 1 month; early post-neonatal mortality, ${}^{m}q_{1\text{-}5}$, i.e. the probability of dying between exact ages 1 and 6 months; and late post-neonatal mortality, ${}^{m}q_{6\text{-}11}$, i.e. the probability of dying between exact ages 6 and 12 months. Neonatal mortality, ${}^{m}q_0$, is largely influenced by congenital defects, birth weight (which may be related to mother's nutritional status) and certain environmental factors; whereas ${}^{m}q_{1\text{-}5}$ and ${}^{m}q_{6\text{-}11}$ are affected by patterns of breastfeeding, supplementation and weaning, as well as environmental factors such as infectious disease.

This chapter aims to document the detailed schedule of mortality in childhood in Africa, as well as how the dynamics of this schedule influences the widely used aggregate childhood mortality indicators — ${}_1q_0$ and ${}_4q_1$. More specifically, it will attempt a comparison of the childhood mortality schedules of historical European and contemporary developing country populations on one hand, and those obtained from DHS birth histories on the other to answer the following questions:

i. Do life tables of the Princeton system reflect the experiences of historical European populations with respect to age-specific death rates in childhood?

ii. What are the characteristics of childhood mortality schedules in Sub-Saharan Africa, how do they vary across in the continent, and what are their implications for the aggregate measures of ${}_1q_0$ and ${}_4q_1$?

iii. To what extent do observed age-at-death structures and mortality schedules in childhood among historical European populations differ from those of Sub-

Saharan African countries and their sub-regions? And if they are significantly different, can this explain the limitations of the Princeton models as descriptions of childhood mortality patterns for most sub-national regions of Africa?

iv. Do the mortality schedules derived from the birth histories present any evidence of a changing pattern of childhood mortality in Sub-Saharan Africa over time?

The age-specific mortality schedules in childhood implied by the respective families of the Princeton model system of life tables are examined to form a basis for subsequent comparisons with life tables obtained from historical and contemporary populations, and from the DHS birth histories for Africa. However, this is preceded by a brief look at what has been observed in some contemporary African populations.

## 6.2 Documented Mortality Schedules in Contemporary African Populations

There exist in the demographic literature very few studies that have systematically investigated the prevailing age-specific mortality schedules in childhood in contemporary developing countries or societies. One such study is that of Cantrelle and Leridon (1971) conducted in a small community in rural Senegal. The distribution of under-5 deaths by age from the data used in the study is graphically presented in Figure 6.1., indicating that the highest proportion of childhood deaths in the population occur in the second year of life. The computed probabilities of dying between specified ages (Figure 6.2) were compared with those recorded for a French population for the period 1740-1829. Whilst the probability of dying decline with age in the historical French population, the schedule of the rural Senegalese population shows an increase in the ${}_nq_x$ at ages 3-5 months, reaching a peak at ages 12-14 months before maintaining a steady decline to age 5 years.

As noted in chapter 2, a similar schedule of mortality is documented by Pison and Langaney (1985) for another rural Senegalese population, and by Hill *et al*. (1983) for different populations in neighbouring Mali. One is, therefore, compelled to ask whether this is the reason for the widespread pattern of high child mortality relative to infant mortality observed

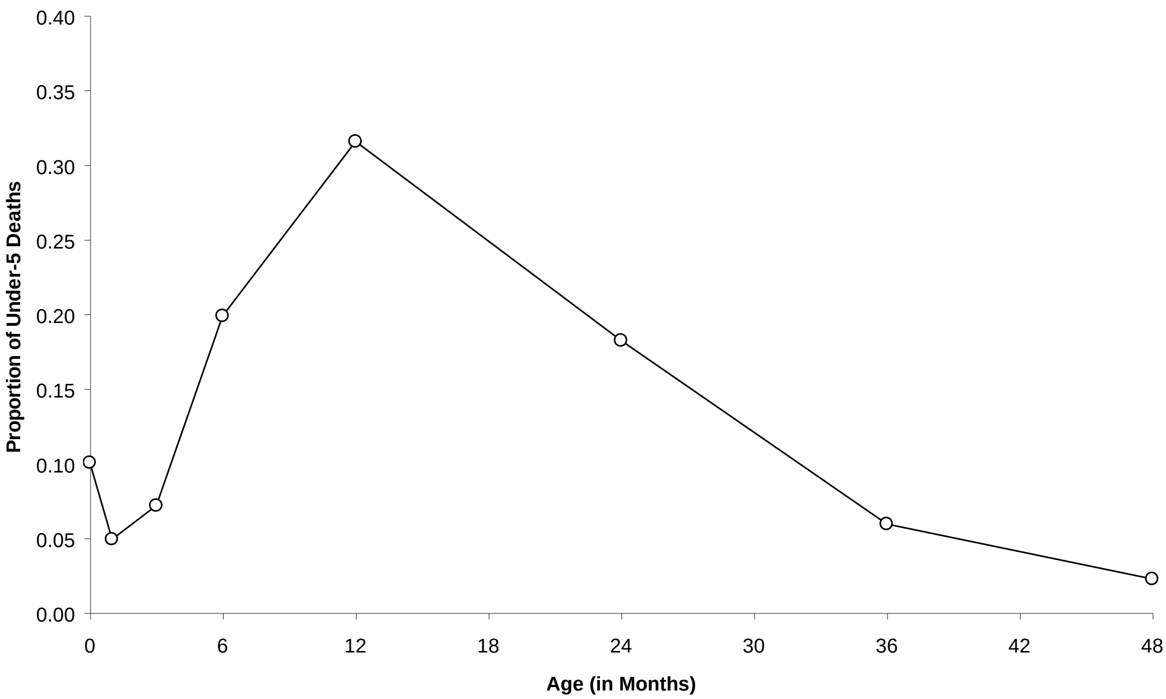



**Figure 6.1:** ***Age-distribution of under-5 deaths in Niakhar, Senegal, 1962-68.***

***Source:*** *Cantrelle and Leridon (1971)*

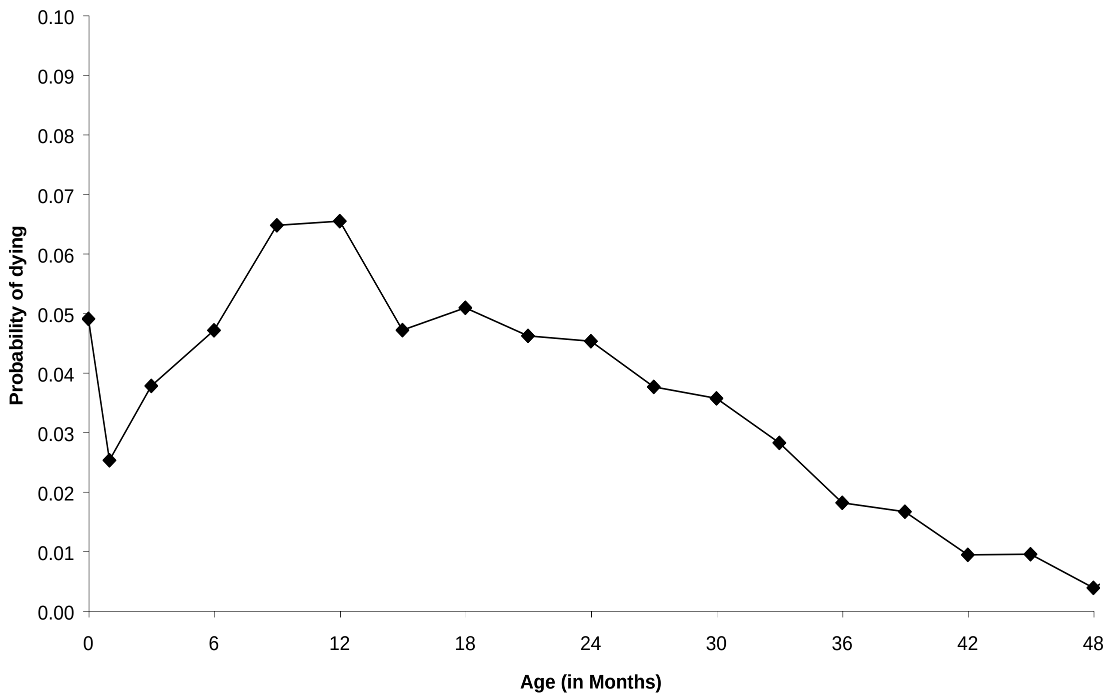



**Figure 6.2:** ***Age-specific probabilities of dying in childhood in Niakhar, Senegal, 1962-68.***
***Source:*** *Cantrelle and Leridon (1971)*

in the previous chapter. Since there is evidence of its existence, how prevalent is this form of childhood mortality schedule across the continent? And is it unique to contemporary African populations? These are what the ensuing sections of the chapter attempt to clarify.

## 6.3 Age-Specific Death Rates in Childhood Implied by the Princeton Model System

Coale *et al.* (1983) did not develop a detailed age breakdown of mortality within infancy and the second year of life in the construction of the Princeton model life tables. However, the Brass and Blacker technique for estimating infant mortality from proportions dying among recent births discussed in Section 5.2.4 can be used to interpolate life table measures for age groups within infancy and the second year of life, which can then be converted to age-specific death rates using conventional formulae. To obtain interpolated age-specific death rates within childhood for ages not included in the original Princeton model life tables, the technique is applied on the Princeton model life tables of level 15 for both sexes[3] of all four families. The fitted $l(x)$ values for all four life tables and their respective model coefficients, $\alpha$ and $\beta$, are presented in Appendix 4. The derived age-specific death rates for age intervals within infancy and early childhood are shown in Figure 6.3. The plotted ${}_{n}m_{x}$ values follow a declining trend with increasing age, reflecting the monotonic decline in death rates for the each of the first five years of life. The usual differences cited for the Princeton families also hold in this case. Apart from the neonatal period, the “East” and “West” patterns are more or less the same throughout infancy, but differ slightly between exact ages 1 and 5 years. Age-specific death rates are higher for the “South” pattern than “North” for the first two years, and slightly lower at ages 3 and 4 years. Another feature of the schedules is all the concave nature of the declines they depict.

[3] In as much as this process can be demonstrated using any life table, the Princeton Life tables of this level are chosen because they are the closest in reflecting the average mortality situation in Sub-Saharan Africa in terms of life expectancy at birth. A detailed assessment that confirms this specifically for the “North” family is given in the next chapter.

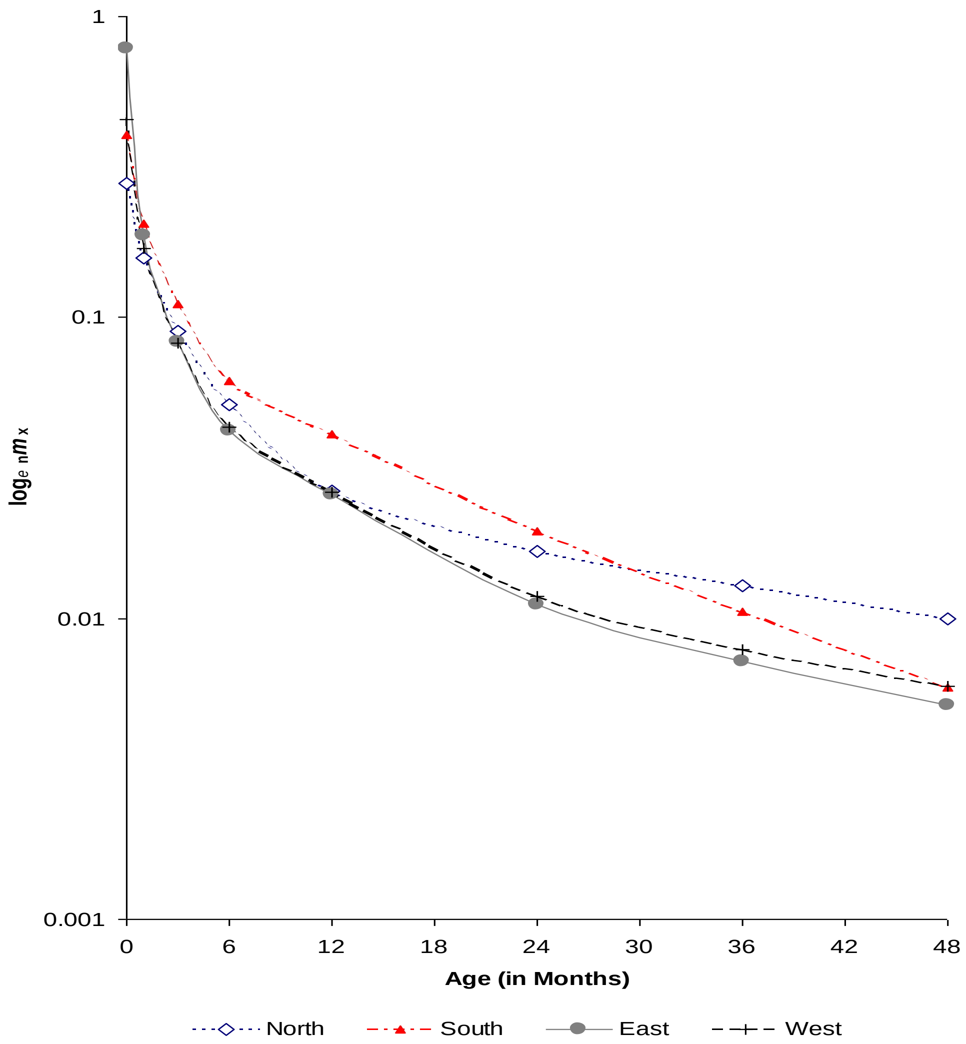



**Figure 6.3:** ***Age-specific mortality schedules in childhood derived for level 15 of the four families of the Princeton model system.***

## 6.4 The Experiences of Selected Historical European Populations

Vital registration series for infant and child mortality have been available for most European countries since the 1870s, and for almost all of Europe since 1900 (Corsini and Viazzo, 1997). Thus every aspect of the decline in infant and child mortality, especially at the end of the nineteenth century and beginning of the twentieth century, is well established for the

European continent. In terms of levels, the data show that in the late nineteenth century, infant mortality levels were high and varied sharply from one country to another, ranging from around 100 per 1,000 live births in Norway and Sweden to up to 250 per 1,000 live births in Germany, Austria and Russia (Mitchel, 1980). With the steepest decline observed in countries with higher level, infant mortality fell right across Europe converging to levels ranging from 20 and 80 per 1,000 live births by the middle of the twentieth century. Further declines in the second half of the century brought ${}_1q_0$ levels to less than 10 per 1,000 live births in Western and Northern Europe; and between 29 and 30 per 1,000 live births in Portugal and many Eastern European countries (Corsini and Viazzo, 1997).

An attempt is made to establish the pattern of mortality in childhood in several historical European populations and compare their experiences with those of contemporary African societies. Although assessments based on risks of dying are to be preferred in comparison of mortality experiences between populations, the investigation has to focus mainly on age-at-death structures. Figure 6.4 shows examples of the age structure of deaths in childhood for

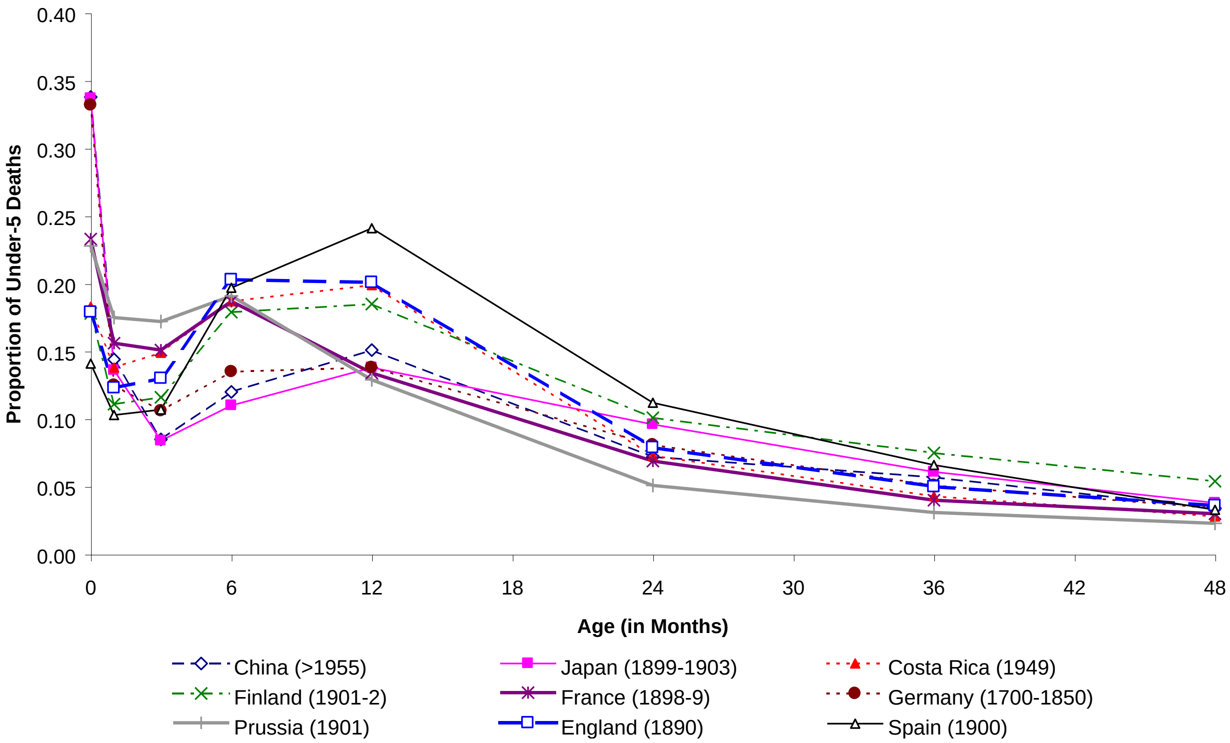



**Figure 6.4:** ***The structure of infant and child mortality in selected historical populations.***
***Source**: Reher (1995)*

selected historical populations, the bulk of which are European. Almost 75% of all childhood deaths occur within the first two years of life; and all the populations demonstrate a similar structure between exact ages 1 and 5 years. At these ages, the proportion of under-5 deaths for all the populations falls consistently with increasing age, with fewer deaths occurring in the fifth year of life than any other childhood period.

The first year of life, however, yields a wide range of mortality structures, with much of the variation occurring in the first month of life, i.e. the proportion of childhood deaths occurring in the neonatal period. Germany (1700-1850), Japan (1899-1903), France (1898-9) and Prussia (1901) had higher proportions of childhood deaths occurring in the first month of life than in any other age bracket, whereas England (1890) had the highest concentration of childhood deaths in the late post-neonatal period, and Spain (1900) in the second year of life. Also, while more deaths occurred in the late post-neonatal period than in the second year of life in France and Prussia, Japan and China — and Finland to a lesser extent — exhibit the reverse pattern. With the exception of Japan and China, proportions of childhood deaths in the two months following the neonatal period were similar to those in the subsequent three months (i.e. ages 3-5 months) for all the populations considered. Moreover, England, Finland and China have nearly twice as many deaths at 6-11 months as at 3-5 months. Nine populations are too few for generalisations to be made. However, they suggest that some form of plateau or reversal in the decline in mortality with age occurred at some point in infancy in a wide range of historical populations. Moreover, their geographical distribution and times of existence are diverse enough for their observed features to be contrasted with contemporary childhood death structures in populations characterised by scarcity or paucity of reliable demographic data — Sub-Saharan Africa especially.

Attention is now switched to the age-specific death rates within childhood. Despite the huge volume of published infant and child mortality data relating to historical European populations in terms of national and sub-national trends, information on the schedule of mortality within infancy and between exact ages 1 and 5 years for these populations is scanty. However, data presented by Breschi and Livi Bacci (1997) for six historical European populations present a glimpse of what mortality schedules in childhood looked like in some nineteenth century European populations. The age-specific death rates, ${}_nm_x$, for these populations are presented in Figure 6.5. They should be interpreted cautiously because they are presented in different age-group classifications.

The data for Belgium (1851-60) and Netherlands (1860-9) cover the first two years of life, but the others focus on infancy only. The similar levels of ${}_{n}m_{x}$ displayed by the Belgian and Dutch data for the second year of life may attest to the quality of the data. In terms of the schedules of mortality depicted, the neonatal death rate, ${}^{m}m_{0}$, is higher than that for the second month of life (i.e. ${}^{m}m_{1}$ for populations presented with monthly death rates) or in the first two post-neonatal months, ${}^{m}m_{1\text{-}2}$ — although only slightly so in the case of Russia (1881-5).

Despite the difference in age-group classifications, all the populations except Switzerland (1881-8) show evidence of a reversal in the declining trend of age-specific death rates within

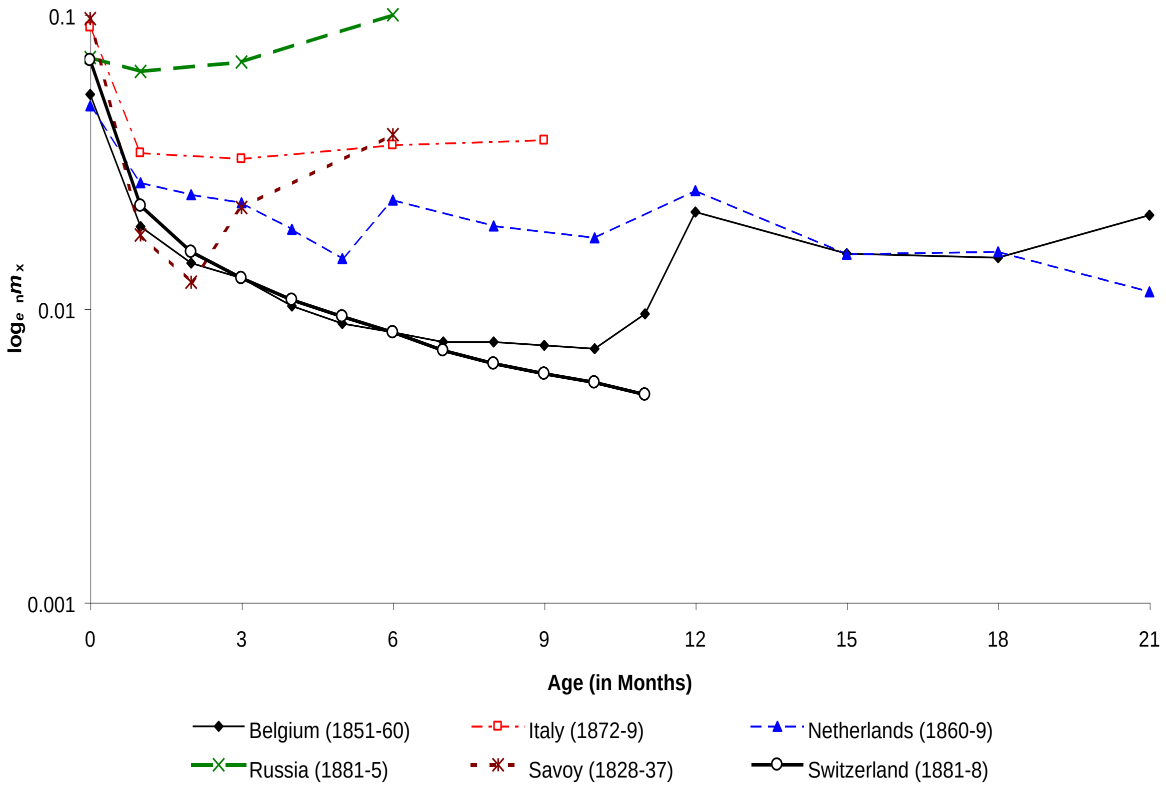



**Figure 6.5:** ***Age-specific mortality rates in the first and second years of life for selected European populations in the nineteenth century.***

***Source**: Breschi and Bacci (1997)*

infancy though in the case of the Netherlands (1860-9) it is unclear whether one is seeing fluctuations in age-specific death rates or a reversal of declining trend at age 6 months. Similarly, Italy's (1872-9) death rates in the post-neonatal ages merely stagnate, albeit a slight increase at age 9 months. However, the remaining three populations, i.e. Russia (1881-5), Savoy (1828-37) and Belgium (1851-60) show clear evidence of reversal of declining trends in ${}_nm_x$ — at age 3 months for Russia and Savoy; and as late as age 11 months in the case of the Belgian population. Another peculiar characteristic of the Belgian schedule is the relatively high death rates in the second year of life compared with those in infancy.

## 6.5 Observed Mortality Schedules from DHS Birth Histories

### *6.5.1 Data Manipulation*

The data used in the ensuing analysis is derived from the record of every child included in the respective DHS birth histories. Using the date of birth to the date of death, in the case of death, or the date of interview otherwise, the individual child records are manipulated to yield total deaths and person-years of exposure by defined age brackets and quinquennia before each survey. The following assumptions are made:

- children who died on the day that they were born are assumed to survive a third of the day, thus contributing an exposure of eight person-hours;

- the survey date is taken to be the mean of the calendar period for which fieldwork lasted, and times prior to the survey as measured from this point.

The timeline of each child's life — i.e. the total period of time for which the child has been exposed to the risk of dying — is followed up to the point of death or censoring at time of interview. It is simultaneously divided up into segments defined by age, and calendar time (in five-year intervals) relative to the survey date. The duration of exposure is the width of the age bracket if the child survives to the next age bracket, or up to the time of death if the child dies within the age bracket. Exposures were computed in days for those who died within birth and the end of first month of life; in months for ages 1 to 24 months; and in years for ages exact 2 and 5 years. All were then converted to years.

The information for all children in every national dataset was then summed by age, sub-national region and reference date to calculate age-specific death rates per person-year of exposure, denoted ${}_{n}m_{x}$ (or ${}^{m}m_{x\text{-}y}$ for age intervals in months), by sub-national region and calendar period. The age brackets in completed months used are 0, 1-2, 3-5, 6-8, 9-11, 12-14, 15-17, 18-20, 21-23, 24-35, 36-47, 48-59. The midpoints of the respective quinquennia prior to each survey are taken to represent the times that the estimated mortality rates prevailed in sub-national region concerned.

### *6.5.2 Depicted Age-at-Death Structures*

The first step to determining whether contemporary childhood mortality in Sub-Saharan Africa is similar to that experienced in Europe is to compare their respective structures of death as far as under-5 mortality is concerned. For each of the 26 countries involved in the study, age-at-death data[4] contained in the birth histories of the most recent survey are used to derive national age-at-death structures for the three most recent quinquennia prior to each survey. The results obtained in terms of proportions of under-5 deaths by age are presented graphically by country in Appendix 5. Since the depicted structures can be regarded as probability density functions (with the area under the graph equalling unity), the median, i.e. the age at which 50% of all under-5 deaths would have occurred, gives an indication as to the average age that children of the population concerned die. Thus, a higher concentration of deaths within the first six months of life (e.g. Liberia in Appendix 5) yields a young median age — in infancy; whilst a greater higher concentration of deaths at older ages (e.g. Niger) produces an average age at death within the childhood ages. Initial indications of mortality pattern can therefore be deduced from the age-at-death structure.

[4] In order to facilitate comparison with those of the historical European populations considered earlier in the chapter, age brackets different from those stated in the data manipulation section are used. These are 0, 1-2, 3-5, 6-11, 12-23, 24-35, 36-47, and 48-59 months.

The derived age-at-death structures do not dramatically differ from those observed among the historical European populations presented in Figure 6.4. The few differences observed are concentrated in the first year of life. Almost every pattern manifested by the past European populations is reflected among those observed in contemporary Sub-Saharan Africa but the proportion of under-5 deaths occurring in the first month of life is generally higher among the African populations than it was in some parts of nineteenth century Europe and other recent non-European populations. The general similarities in structure, though, further attests to the validity and reliability of the mortality data contained in the DHS birth histories.

### *6.5.3 Method of Exploration of $_nm_x$ Estimates*

Clear evidence of heaping at age 12 months is apparent from the examination of the age structure at death in childhood. To allow for this problem, the following decisions and assumptions are made in the ensuing assessment of childhood mortality schedules:

a. A slightly different set of age groups is used that aims at minimising the effect of the heaping of age-at-death in the birth histories at 12 months. The age groups are 0, 1-2, 3-5, 6-8, 9-14, 15-23, 24-35, 36-47, and 48-59 months.

b. The age-specific death rates are treated as if they are constant throughout the age groups they refer to. This implies, therefore, that for any given sub-national population, the death rate in the last quarter of infancy is taken as the same as that in the first quarter of the second year of life.

c. Implausible variations were observed in $_1m_4$, i.e. the mortality rate in the last year of early childhood. These probably reflect sampling error and heaping on age 5 years. Thus, the identification of distinct mortality patterns in childhood is restricted to ages up to 4 years.

The process of classifying mortality schedules in infancy and early childhood is based on a chained comparison of consecutive $_nm_x$ levels for the age brackets in each of the childhood periods. Neonatal mortality is always higher than mortality rate in the subsequent month or couple of months. Thus, comparison of age-specific mortality rates in infancy start with the 1-2 months age group against the 3-5 months age group. The comparisons locate ages at which the initial decline in mortality rate from the neonatal period is reversed, thereby creating “trough”- and “peak”-like features in the age-specific mortality schedule depending on the number of reversals that occur.

The next issue for consideration in the process of exploring the nature of age-specific death rates was the period over which sets of ${}_nm_x$ estimates should refer to for each sub-national population — i.e. the factor of calendar time. Since the respective national Demographic and Health Surveys were conducted at different dates, focussing on the precise dates ${}_nm_x$s refer to is difficult.

It could be argued, especially from the experiences of historical European populations, that 15 years — i.e. the period each national survey is set to cover in this analysis — is too short a time for childhood mortality patterns to transform significantly from one form to another. This argument favours deriving an average set of ${}_nm_x$ from all sets of estimates available for each sub-national region. However, the economic and epidemiological situation in the continent have undergone significant changes since the late 1970s. The 1980s saw economic decline and hardship over much of Sub-Saharan Africa (National Research Council, 1993); and the late 1980s and early 1990s marked the onset of the impact on mortality of the AIDS epidemic in the continent. For these reasons, averaging by the decade in which the estimates fall seems pragmatic. Each survey provides sub-national estimates falling in two decades and, because most surveys were conducted in the late 1980s and early 1990s, the bulk of the ${}_nm_x$ estimates for sub-national regions fall in the 1980s with few in the 1970s. Therefore, the ensuing analysis is restricted to the two decades of the 1980s and the 1990s — the former characterised by economic reversals, and the latter by both economic problems and the impact of the AIDS epidemic.

### *6.5.4 Identified Mortality Schedules in Childhood*

Using the sets of ${}_nm_x$ averages derived for each sub-national region for the 1980s and the 1990s, the identification of distinct mortality schedules in infancy started by referring to those derived for the Princeton model system (and shown in Figure 6.3). Are there childhood mortality schedules among sub-national regions in Sub-Saharan Africa in the 1980s and 1990s that manifest characteristics similar to those implied by the Princeton model system in terms of a consistent decline in age-specific death rates from the neonatal period?

Out of the 160 national and sub-national regions that this study focuses on, one (Western Cape in South Africa) had its estimates for the 1980s discarded because they appeared manifestly unreliable. In the remaining 159 regions, the ${}_{n}m_{x}$ estimates were subjected to the chained comparison of consecutive estimates and classified according to the location of the first reversal of the declining schedule of age-specific death rates. At a glance, the prevalence of mortality schedules with fluctuations in death rates between ages 2 and 5 is quite significant but probably reflects sampling error. All schedules are therefore assumed to maintain a declining risk of death with increasing age from 2 years onwards. This approach resulted in five groups of populations whose respective ${}_{n}m_{x}$ estimates are plotted and presented in Figure 6.6 on a logarithmic scale, together with their overall averages — on which subsequent general descriptions are based — indicated in bold.

Twenty-two sub-national regions (i.e. 13.8% of all considered) have infant mortality schedules characterised by consistent decline — although at various rates — after the neonatal period, similar to those implied by the Princeton model life table system. For ease of identification, this grouping is henceforth referred to as the “Princeton Type” Schedule though no attempt is made at this stage to compare the individual regional schedules to those of the different families of the Princeton model system. Despite the neat decline depicted by the group average, a few schedules manifest "step"-like declines in age-specific death rates especially in the post-neonatal ages, indicating that the differences between some consecutive ${}_{n}m_{x}$ estimates are minimal.

The second group comprises only 7 regions (i.e. 4.4% of the total). It is characterised by reversal of the decline in age-specific death rates in the 15-23 months age bracket as shown in the upper right panel of Figure 6.6. The subsequent decline in age-specific death rates with increasing age following the reversal creates a “hump”-like feature located wholly in the second year of life. For identification purposes, this is called the “15$^{th}$ – 23$^{rd}$ Month Hump” Mortality Schedule.

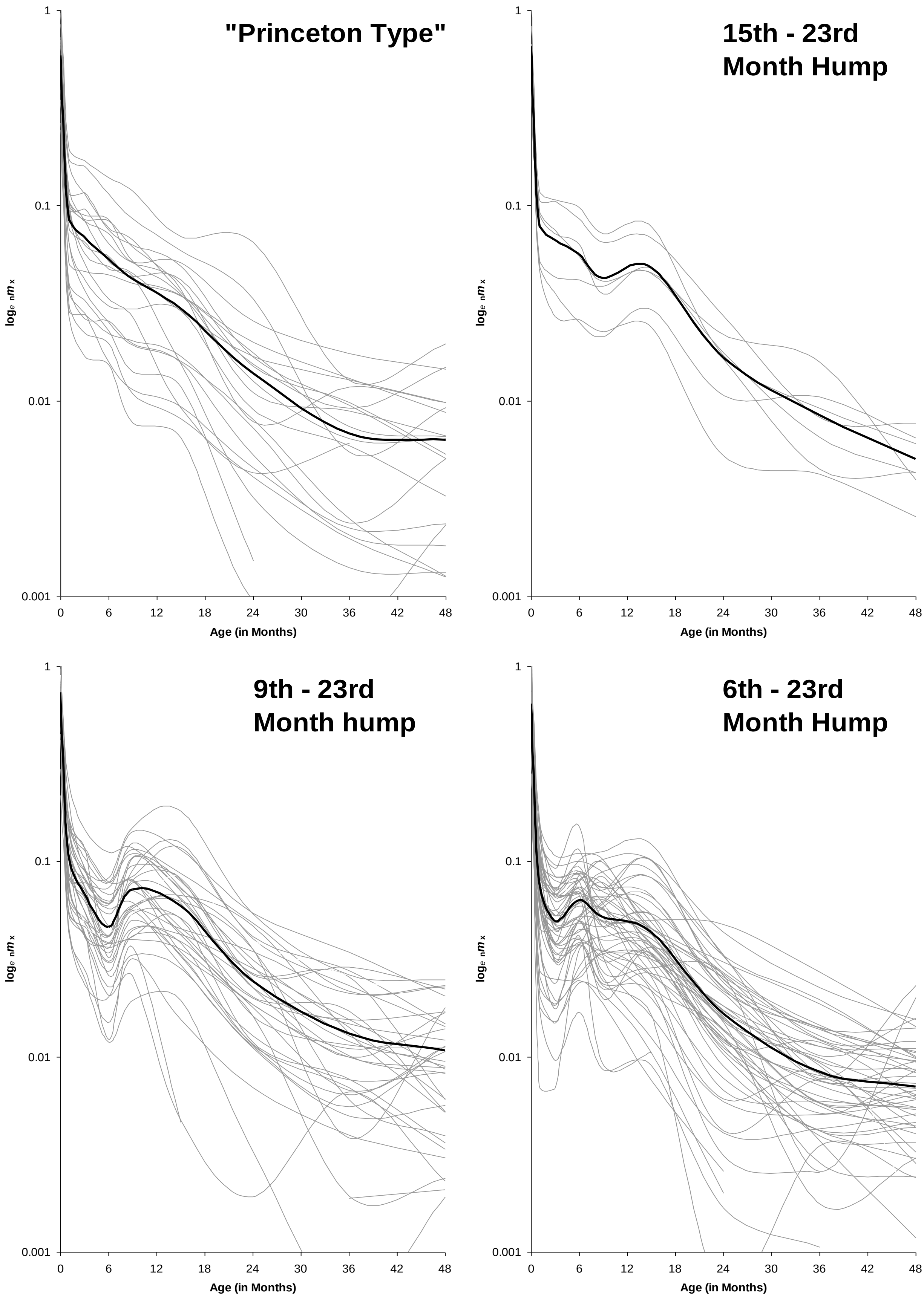
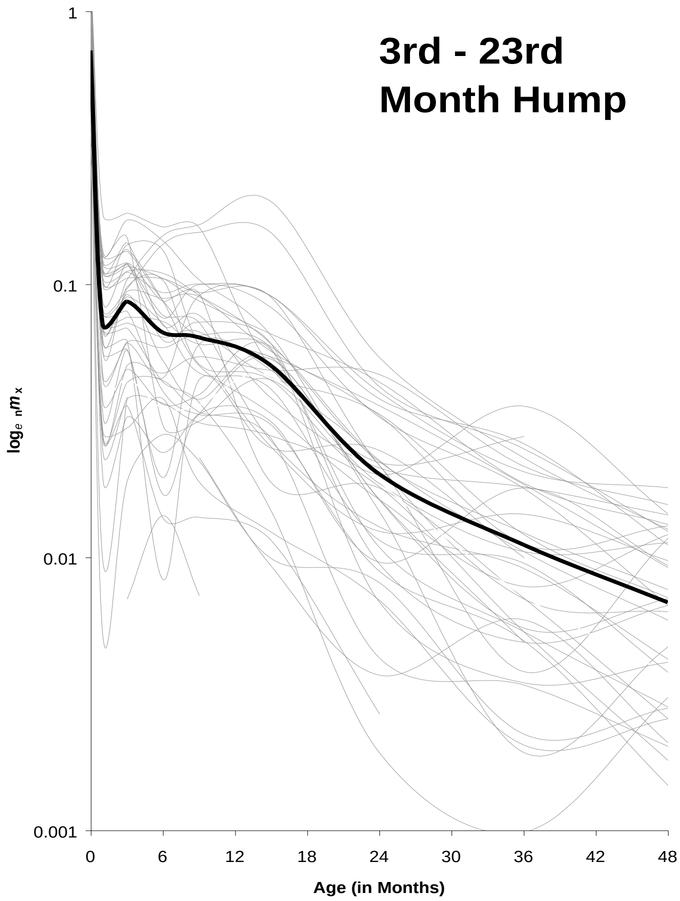



**Figure 6.6:** ***Identified distinct schedules of mortality in childhood based on 1980s sub-national averages.***

**Figure 6.6 — *continued*.**




The third age pattern of mortality consists of 36 sub-national regions (i.e. 22.5% of the total). These are characterised by the reversal of falling age-specific risks of death at ages 9-14 months as shown in the lower left panel of Figure 6.6. As can be seen clearly from the group average, the increase in the risk of dying from age 9 months produces a "hump" in the mortality schedules of region in this group which tapers off towards the end of the second year of life. It is also apparent that the decline in ${}_n m_x$ from age 2 years is also dampened in these populations, producing relatively higher levels of mortality in the last three years of early childhood than in populations without a hump at 9-23 months. A few individual regional schedules do have steeper rates of decline in the risk of dying in these last three years. This schedule is referred to as the "9$^{th}$ – 23$^{rd}$ Month Hump" Mortality Schedule.

The fourth group comprises 54 regions (34%). It is characterised by a continued decline in ${}_n m_x$ from the neonatal period through to the 3-5 months age bracket and a reversal in the 6-8 month age bracket. Individual sub-national regions, however, display different trends between the common reversal at age bracket 6-8 months and the end of the second year of life. In a few regions mortality then tails of rapidly, while in others it continues to rise into the second year of life producing a very pronounced "hump". The average of the combination — as shown in the lower right panel of Figure 6.6 — displays a wide "hump", and this is referred to as the "6$^{th}$ – 23$^{rd}$ Month Hump" Mortality Schedule.

The remaining 40 sub-national regions represent 25% of the total. They display the fifth and final distinct mortality schedule in childhood characterised by the early reversal of falling risks of death in the 3-5 month age bracket. Like the previous group, individual regional schedule manifest different trends in age-specific death rates from the point of the reversal up to age 23 months. Their group average has the widest "hump" among all identified distinct schedules of childhood mortality, which spans the ages 3 and 23 months, and hence is called the "3$^{rd}$ – 23$^{rd}$ Month Hump" Mortality Schedule. It appears to be slightly dented between 6 and 8 months due to the countering effects of the averaging process.

The same process of ${}_{n}m_{x}$ chained comparison and plotting of regional schedules was repeated using regional estimates referring to the decade of the 1990s. No estimates were available for the four Liberian regions and Burundi since their respective surveys were conducted in the 1980s. An additional three regions (viz.: Borkou-Ennedi-Tibesti [B.E.T.] in Chad, Nairobi in Kenya, and Western Cape in South Africa) had their estimates discarded because they appeared suspect. The analysis of the ${}_{n}m_{x}$ estimates for the remaining 152 regions yielded the same mortality schedules in childhood as obtained with the 1980s estimates and are as presented in Figure 6.7. Theoretically, any different outcome would have cast more doubt on the validity and quality of ${}_{n}m_{x}$ estimates and the data as a whole. The distribution in the 1990s is as follows: 11 regions (6.9%) displayed the "Princeton Type"; 5 regions (3.1%) had the "15$^{th}$ – 23$^{rd}$ Month Hump" Mortality Schedule; 35 regions (21.9%) manifested the "9$^{th}$ – 23$^{rd}$ Month Hump" Mortality Schedule; 61 regions (38.1%) displayed the "6$^{th}$ – 23$^{rd}$ Month Hump" Mortality Schedule; and 40 regions (25%) had the "3$^{rd}$ – 23$^{rd}$ Month Hump" Mortality Schedule.

Considering the fact that eight regions are unclassified in the set of the 1990s schedules, the prevalence of the different mortality schedules in childhood in the 1990s does not appear to be significantly different from that of the 1980s. In particular, the second, third and fifth identified mortality schedules above show more or less the same frequencies in both decades.

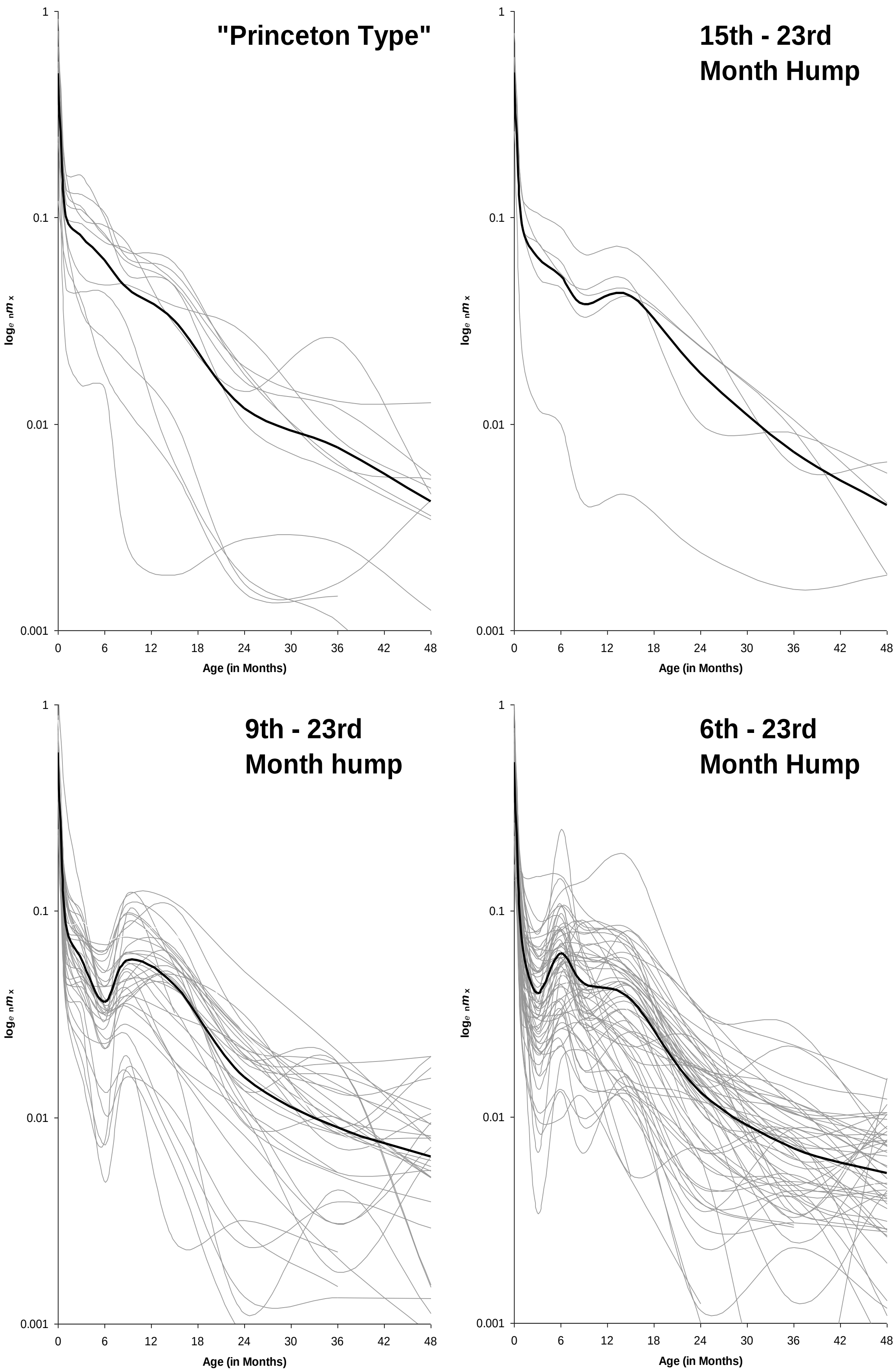
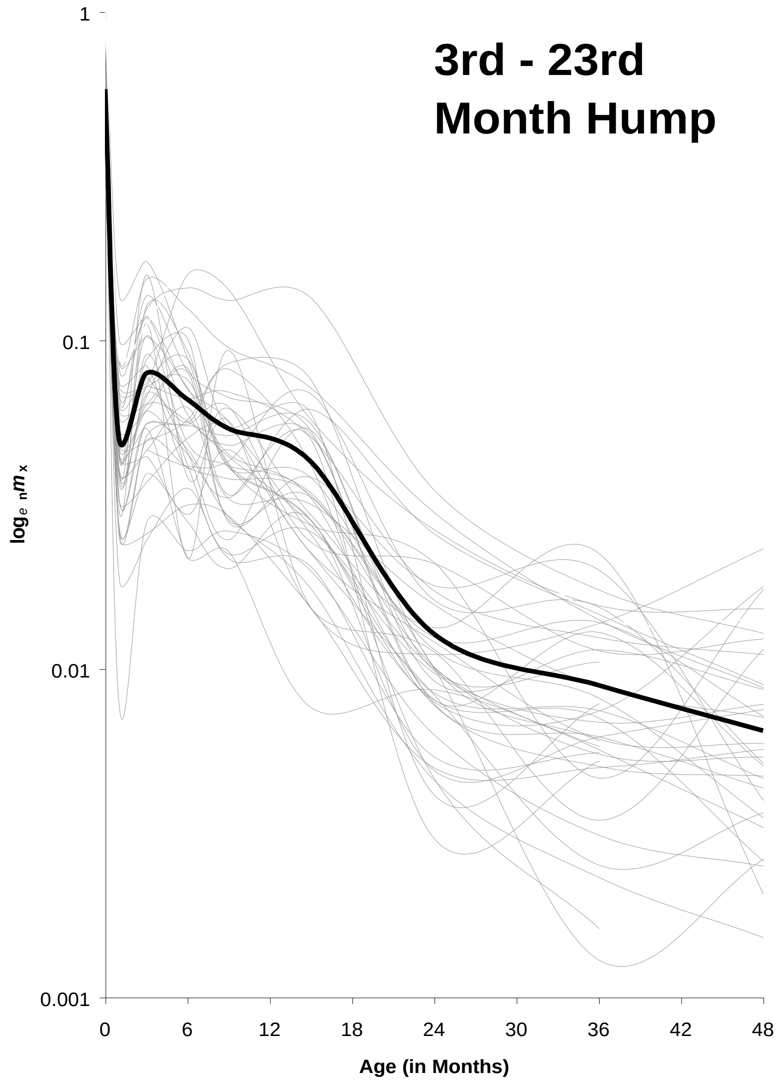



**Figure 6.7:** ***Identified distinct schedules of mortality in childhood based on 1990s sub-national averages.***

**Figure** 6.7 **—** ***continued*****.**




However, a simple cross-tabulation of infancy schedules displayed in the 1980s against corresponding schedules in the 1990s reveals that transformations of schedules occurred in all possible forms and directions. These are presented in Table 6.1. A simple $\chi^2$-test produces only weak evidence in support of any systematic association between sub-national regional childhood mortality schedules in the 1980s and the 1990s. Even the exclusion of the schedule displayed by the least number of regions, i.e. those with the "15$^{th}$ – 23$^{rd}$ Month Hump", does

**Table 6.1:** ***Distribution of transformed childhood mortality schedules between the 1980s and the 1990s.***

| ***Schedule in 1980s:*** | ***Schedule in 1990s:*** "Princeton Type" | 15th - 23rd Month Hump | 9th - 23rd Month Hump | 6th - 23rd Month Hump | 3rd - 23rd Month Hump | Total |
|---|---|---|---|---|---|---|
| "Princeton Type" | 3 | 2 | 5 | 7 | 5 | 22 |
| | *14%* | *9%* | *23%* | *32%* | *23%* | *100%* |
| 15th - 23rd Month Hump | 0 | 0 | 2 | 5 | 0 | 7 |
| | — | — | *29%* | *71%* | — | *100%* |
| 9th - 23rd Month Hump | 3 | 1 | 13 | 13 | 5 | 35 |
| | *9%* | *3%* | *37%* | *37%* | *14%* | *100%* |
| 6th - 23rd Month Hump | 3 | 1 | 8 | 25 | 15 | 52 |
| | *6%* | *2%* | *15%* | *48%* | *29%* | *100%* |
| 3rd - 23rd Month Hump | 2 | 1 | 7 | 11 | 15 | 36 |
| | *6%* | *3%* | *19%* | *31%* | *42%* | *100%* |
| Total | 11 | 5 | 35 | 61 | 40 | 152 |
| | *7%* | *3%* | *23%* | *40%* | *26%* | *100%* |

$\chi^2$ (16 df) = 20.63; *p-value* = 0.193

not strengthen the evidence in support of the association to a significant level. Classifying it as a "Princeton Type" schedule yields a $\chi^2$(9 df) value of 14.31, and a *p*-value of 0.122 — still representing weak evidence of a systematic association. Notwithstanding this, it is quite apparent from Table 6.1 that in instances where transformations occurred between the two periods, higher proportions got transformed into the "6th – 23rd Month Hump" Mortality Schedule — the most prevalent schedule in both periods. On the other hand, transformations into the relatively light mortality schedules of the "15th – 23rd Month Hump" and the "Princeton Type" in the 1990s were uncommon. No schedule persisted between the two periods in half the regions manifesting it. The "6th – 23rd Month Hump" was the closest with 48%. However, the demographic plausibility of some of these transformations is open to

**Table 6.2:** ***Strength of evidence in support of any association between regional schedules in the 1980s and 1990s by continental sub-region.***

| **Continental Sub-Region** | **$\chi^2$ value (degrees of freedom)** | ***p*-value** |
|---|---|---|
| Sahel West Africa | 12.95 ( 4) | 0.012 |
| Coastal West Africa | 8.21 (16) | 0.942 |
| Middle Africa | 14.00 (16) | 0.599 |
| Eastern Africa | 19.36 (16) | 0.250 |
| Southern Africa | 16.45 (12) | 0.171 |

question, especially the relatively few instances of transformations from the "9$^{th}$ – 23$^{rd}$" or "6$^{th}$ – 23$^{rd}$ Month Hump" to the "Princeton Type" Schedule.

The search for association between the schedules displayed in the two periods was also pursued at the sub-continental. Summary test statistics are presented in Table 6.2. The "Princeton Type" Schedule and the "15$^{th}$ – 23$^{rd}$ Month Hump" were not found in any sub-national region in Sahel West Africa at any of the periods considered. Because of this rather narrowed range of schedules, overwhelming evidence exists in support of a systematic association between schedules that prevailed in this continental region in the 1980s and 1990s. The evidence is statistically significant at 95% confidence level. For all the other sub-continental regions the evidence to support the existence of an association between schedules manifested in the two periods remains weak as shown by their respective p-values in Table 6.2. In essence, this result suggests that generally the numerical distributions of schedules cannot explain the volume of transformations that had occurred between the 1980s and 1990s, thus necessitating a geographical or spatial assessment to make some sense out of the distributions of the schedules in the two periods. This procedure will essentially attempt to establish whether there existed contiguous geographical entities comprising two or more sub-national regions irrespective of country of location that showed similar changes in mortality schedules in childhood between the 1980s and 1990s; and another group of regions displaying the reverse process thus making up the numbers that form the distributions for the two periods.

Since the mapping of manifested schedules has the potential of displaying how the different schedules relate to each other geographically in terms of the intensity of mortality they individually depict relative to a consistently declining "Princeton Type" one, it is deemed worthwhile to chart the implications of each schedule for levels of infant and child mortality. This is expected to help identify and find convincing explanations for situations where a region with light mortality schedule is bordered by another region or regions with an extreme and relatively heavier mortality schedule.

### *6.5.5 Geographical Distribution of Identified Schedules*

The geographical distributions of the four identified average schedules are presented in Figure 6.8 by period. With the exception of the Sahel, every sub-continental region shows a prevalence of all schedules in both periods, although some appear to have higher concentrations of a particular schedule during one of the periods than other areas. An attempt will be made to arrive at a succinct comparison of the situations that prevailed in the two periods starting with the respective schedule distributions of the 1980s.

The available data suggest that the "Princeton Type" Schedule was more prevalent in Eastern and Southern Africa than in West and Middle Africa in the 1980s. Its geographical distribution in Eastern Africa stretched from the central parts of Ethiopia and south-westwards through much of Kenya and Tanzania. In southern Africa it covered Mashonaland in Zimbabwe — with the exception of Mashonaland Central; the western end of Zambia; the region of Tête in Mozambique; and Mpumalanga, Northern Cape and Eastern Cape in South Africa. It is not found in the coastal belt of countries except in Eastern Cape in South Africa. Only isolated sub-national regions manifested the "Princeton Type" Infancy Schedule in West Africa. None of them lie in the Sahelian countries. In Middle Africa, the mortality schedule in question is centred on the southern Chadian regions of Logone Oriental and Moyen Chari, and the adjacent Health Region III of the Central African Republic (see Figure 6.8).

The "3rd - 23rd Month Hump" Schedule was equally prevalent in Southern Africa and West and Middle Africa. Recall that this group of schedules is rather unstable. Fairly small changes in ${}^{m}m_{6\text{-}8}$, ${}^{m}m_{3\text{-}5}$ or ${}^{m}m_{1\text{-}2}$ can transform it into a narrower hump or even a "Princeton Type"

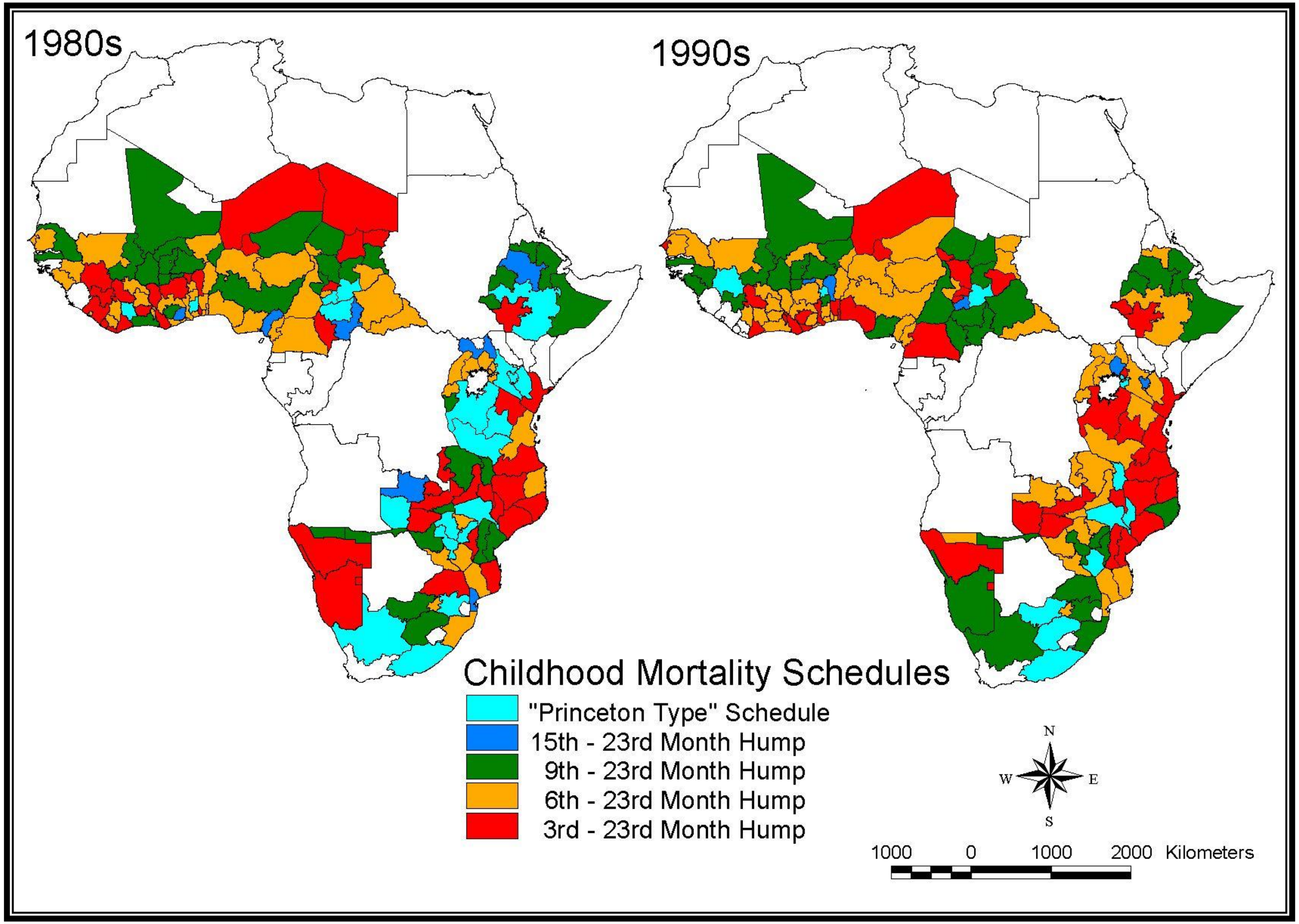



**Figure 6.8:** ***Geographical distribution of identified childhood mortality schedules in the 1980s and 1990s in Sub-Saharan Africa.***

Schedule. In West Africa in the 1980s, it was clearly the dominant childhood mortality schedule in central and southern Guinea, much of Liberia and some adjacent regions in western Côte d'Ivoire. Another geographical area where it was evidently prevalent stretches from north-eastern Côte d'Ivoire through northern Ghana, excluding the Upper West and East Regions, to northern Togo and Benin. North-westwards, it was also common schedule in the northern parts of Niger and Chad.

In Southern Africa, the "3rd - 23rd Month Hump" Schedule was prevalent in a large contiguous geographical entity covering southern, central and parts of northern Zambia, central and southern Malawi, and northern Mozambique. Pockets of it were also evident in Manicaland in Zimbabwe, Inhambane in Mozambique, and Northern Province in South Africa. It was also found in Namibia Central and South. This schedule is often bordered by sub-national regions displaying the "Princeton Type" Schedule. This attests to its main characteristic described earlier.

The "6th - 23rd Month Hump" and the "9th - 23rd Month Hump" Schedules — which have a greater potential to influence the relative levels of ${}_1q_0$ and ${}_4q_1$ — were more prevalent in West and Middle Africa. The latter schedules, which are most likely to produce high ${}_4q_1$ estimates relative to ${}_1q_0$, dominated the middle part of the Sahel West Africa in the 1980s. The pattern covered northern and central Mali, the whole of Burkina Faso, and the neighbouring Upper West and East regions of Ghana. The schedule was also displayed by Senegal North East and South in the west of the continental sub-region; and by eastern Niger, southern Chad and central Nigeria in the east of the sub-region. However, the schedule appeared only in pockets in Southern Africa in the 1980s. These comprise northern Namibia, northern Zambia and Malawi, middle part of Mozambique, and the adjacent regions of South Africa, North West and Free State. Many Ethiopian sub-national regions also manifested this mortality schedule in the 1980s. The "6th - 23rd Month Hump" Schedule was also more prevalent in West and Middle Africa than Eastern and Southern Africa. Finally, fewer than eight sub-national regions in the entire continent displayed the "15th - 23rd Month Hump" Schedule in the 1980s.

In the period of the 1990s, significant changes were observed in the prevalence and geographical distribution of the identified mortality schedules, most of which occurred in the continental sub-regions of Eastern and Southern Africa. Most prominent among the changes is the apparent disappearance of the "Princeton Type" Schedule in Eastern Africa, except for the Nyanza region of Kenya; and fewer appearances in Southern African countries than was the case in the 1980s. This is a clear indication that Sub-Saharan African mortality schedules in childhood are increasingly becoming characterised by an excessive mortality "hump" within the first two years of life relative to the "Princeton Type" Schedule. The affected sub-national regions happen to fall in countries for which evidence has shown recent increases in ${}_5q_0$ levels as documented in Chapter 4.

The "9th - 23rd Month Hump" Schedule became concentrated in four main areas in the continent in the 1990s. These are:

i. the area covering the middle part of Sahel West Africa where it also prevailed in the 1980s;

ii. much of middle Africa covering southern Chad, northern Cameroon and the whole of the Central African Republic except for the Health Region V in the east;

iii. northern and eastern Ethiopia; and

iv. south-western and south-eastern parts of the continental sub-region of Southern Africa.

With the exception of the fourth area, all these regions are among those shown to display unusually high levels of ${}_4q_1$ relative to ${}_1q_0$ in Chapter 5 (see Figure 5.11).

The "6th - 23rd Month Hump" Schedule prevailed in the 1990s in many West African sub-national regions that displayed the "3rd - 23rd Month Hump" Schedule in the 1980s; and was more prevalent in Eastern and Southern Africa than in the earlier decade. The rather narrow "15th - 23rd Month Hump" Schedule is virtually becoming non-existent in the continent.

## 6.6 Discussion and Conclusion

### *6.6.1 Implications of Identified Schedules for Infant and Child Mortality*

It is worth re-iterating at this point the fact that the average group schedules are by no means the definite or true childhood mortality schedules prevailing in Sub-Saharan Africa. As can be seen in the respective average sub-national schedules for the two decades concerned, the prevailing "humps" are varied in terms of start and end points in the childhood ages, as well as height or intensity.

To assess the implications of each identified childhood mortality schedule with a "hump" for levels of infant and child mortality, one can compare the shape of each schedule to an imaginary one that is purged of any reversal in age-specific death rates. Thus it is similar to the "Princeton Type" but not necessarily with the same rate of decline in ${}_{n}m_{x}$. In each case the imaginary schedule is obtained by joining the base of the "trough" created by the onset of the hump to the level of ${}_{1}m_{2}$, thus clearly showing the hump as a representation of excess mortality (see Figure 6.9). The graphs should be interpreted with caution since they represent average group cases used for a rather simplified demonstration of the effects of the respective humps on summary childhood mortality indicators. The "15$^{th}$ – 23$^{rd}$ Month Hump" schedule — as the location of the hump suggests — has implications for child mortality only and necessarily implies higher child mortality relative to infant. The degree of the disparity between the two aggregate measures of childhood mortality depends on how extreme ${}^{m}m_{15\text{-}23}$ is relative to ${}^{m}m_{9\text{-}14}$. Such a schedule could therefore be associated with mortality patterns ranging from the Princeton "North" family to those termed "unusual" in the previous chapter.

The excess mortality associated with the "9$^{th}$ – 23$^{rd}$ Month Hump" schedule covers the last three months of infancy and the entire second year of life. In terms of infant mortality, this schedule differs from the "Princeton Type" by having higher mortality in the late post-neonatal period. The excess mortality in the second year of life outweighs that in infancy thus implying a situation similar to the first schedule considered — i.e. higher child mortality relative to infant albeit at varying degrees depending on the levels of ${}^{m}m_{9\text{-}14}$ and ${}^{m}m_{15\text{-}23}$. At the high mortality level prevailing in Sub-Saharan Africa, it is unlikely that such schedules will yield infant-to-child mortality relationships similar to those portrayed by the Princeton

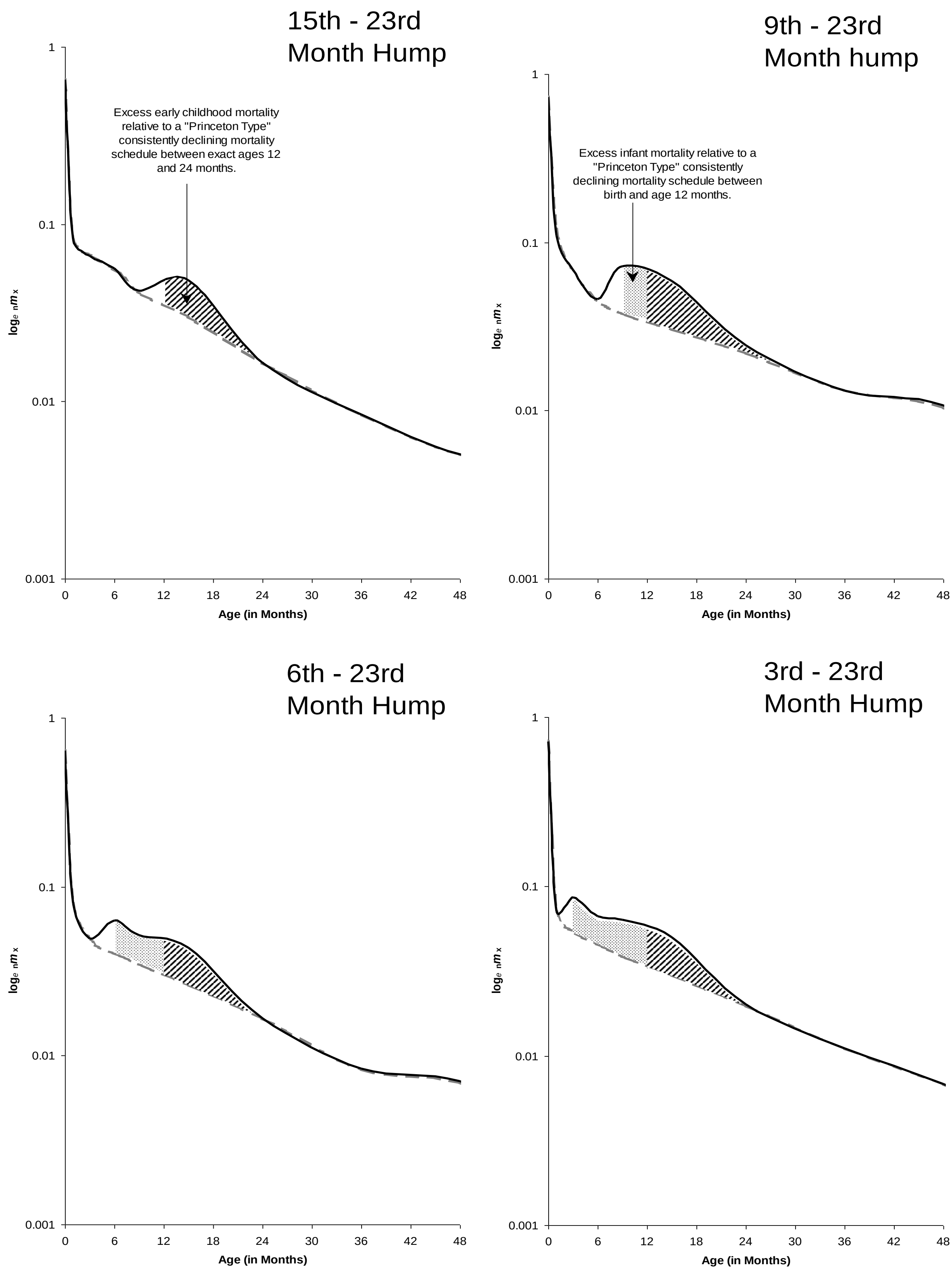



**Figure 6.9:** ***Demonstration of the implications of identified childhood mortality schedules for infant and child mortality relative to a consistently declining "Princeton Type" pattern of childhood mortality.***

"North" pattern family. They will be associated with the "unusual" patterns of very high child relative to infant mortality.

The hump widens by another three months in the case of the "6th – 23rd Month Hump" schedule, thus covering the second half of infancy and the whole of the second year of life. This again implies excess mortality in the late post-neonatal period relative to the "Princeton Type" schedule. Compared with the "9th – 23rd Month Hump" schedule, the disparity between infant and child mortality is reduced. Notwithstanding, the schedule constitutes a distortion of the pattern of mortality away from the "Princeton Type".

The assessment of the implications of the final schedule can be approached in two ways both of which point to the same conclusion. First, in instances where ${}^{m}m_{3\text{-}5}$ is significantly high relative to ${}^{m}m_{1\text{-}2}$, and ${}^{m}m_{6\text{-}8}$, ${}^{m}m_{9\text{-}14}$ and ${}^{m}m_{15\text{-}23}$ fail to drop to relatively lower levels that yield the consistent decline characteristic of the "Princeton Type" schedule, then the widest hump possible emerges in the resulting schedule. The hump affects all the first two years of life except the neonatal period and first part of the early post-neonatal period. This effectively implies higher overall childhood mortality with the disparity between child and infant mortality ranging from minimal to extreme degree depending on the levels of the death rates between 9 and 23 months of age. Secondly, in cases where the disparity is minimal, the schedule approaches a "Princeton Type" pattern at high mortality levels, or end up more like the "15th – 23rd Month Hump" schedule. Otherwise, the schedule is significantly distorted away from the "Princeton Type" toward the "unusual" patterns of high child relative to infant mortality. The second and relatively simpler way of arriving at the same conclusion is to see these schedules as akin to Princeton models in which mortality ages 1-2 months is depressed.

### *6.6.2 Conclusion*

Lack of sufficient historical mortality data hinders a comparison of the childhood mortality experiences of historical European populations with those depicted by the respective families of the Princeton model system. However, the analysis presented in this chapter has shown that childhood mortality schedules characterised by a reversal in declining trend at different ages did prevail among some European populations in the nineteenth century. It cannot be established, though, whether it was to the scale observed in Sub-Saharan Africa.

The factors that governed and shaped the transformation of mortality levels and patterns in childhood in Europe from historical times to date differ from those that prevail in contemporary Sub-Saharan Africa, and probably much of the developing world. To start with, the age-specific death rates in childhood that characterised Europe in the nineteenth century were much lower that those prevailing in the greater part of contemporary Sub-Saharan Africa (compare Figure 6.5 with Figures 6.6 and 6.7). Also, sustained economic and human development through the industrial revolution and urbanisation to present welfare democracies greatly dictated the realisation of the extremely low levels of infant and child mortality currently prevailing in the continent of Europe. Against this background, therefore, it is probable that towards the end of the nineteenth century, European populations started manifesting childhood mortality schedules similar to those implied in the Princeton Model Life Table System.

Sub-Saharan Africa, on the other hand, is still in its early stages of mortality transition, and has been faced with economic stagnation or reversals since the late 1970s, thereby producing differential outcomes in efforts to curb preventable childhood deaths and attempts to favourably alter the disease environment. These have recently become compounded by the AIDS epidemic. These setbacks constitute the most probable reason for the most significant finding emanating from the analysis, i.e. the fact that almost all sub-national regions of Sub-Saharan Africa display childhood mortality schedules characterised by a "hump" of what can be regarded as excessive mortality within the first two years of life.

In summary, the available DHS data — despite the strain they have been subjected to by the mode of analysis adopted in this chapter — have shown that:

- Age-specific death rates in childhood for most African sub-national populations are characterised by a "hump" of excess mortality from the late post-neonatal period to the second year of life. It renders the schedules completely different from those of the Princeton model system, and manifests itself in various forms in terms of location on the age scale and height. On average, it sets in by age 6 months.

**Table 6.3:** ***Cross-classification of observed exploratory patterns based on DHS 2 data against mortality schedules based on 1980s sub-national averages.***

| ***Exploratory Pattern based on DHS Phase 2 Data*** | ***Schedule of mortality in 1980s:*** | | | | **Total** |
|---|---|---|---|---|---|
| | "Princeton Type" | 9th - 23rd Month Hump | 6th - 23rd Month Hump | 3rd - 23rd Month Hump | |
| *"Sahelian"* Pattern | – – | 4 *(29%)* | 4 *(29%)* | 6 *(43%)* | **14 *(100%)*** |
| *"North Plus"* Pattern | 2 *(9%)* | 8 *(36%)* | 8 *(36%)* | 4 *(18%)* | **22 *(100%)*** |
| Princeton North | 5 *(33%)* | 4 *(27%)* | 2 *(13%)* | 4 *(27%)* | **15 *(100%)*** |
| Princeton South | 1 *(33%)* | – – | – – | 2 *(67%)* | **3 *(100%)*** |
| Princeton West | 2 *(50%)* | – – | 1 *(25%)* | 1 *(25%)* | **4 *(100%)*** |
| **Total** | **10 *(17%)*** | **16 *(28%)*** | **15 *(26%)*** | **17 *(29%)*** | **58 *(100%)*** |

$\chi^2$ (12 df) = 16.97; *p-value* = 0.151

**Table 6.4:** ***Cross-classification of observed exploratory patterns based on DHS 3 and 4 data against mortality schedules based on 1990s sub-national averages.***

| ***Exploratory Pattern based on DHS Phases 3 and 4 Data*** | ***Schedule of mortality in 1990s:*** | | | | **Total** |
|---|---|---|---|---|---|
| | "Princeton Type" | 9th - 23rd Month Hump | 6th - 23rd Month Hump | 3rd - 23rd Month Hump | |
| *"Sahelian"* Pattern | – – | 9 *(39%)* | 9 *(39%)* | 5 *(22%)* | **23 *(100%)*** |
| *"North Plus"* Pattern | 6 *(9%)* | 15 *(23%)* | 26 *(41%)* | 17 *(27%)* | **64 *(100%)*** |
| Princeton North | 1 *(5%)* | 5 *(26%)* | 7 *(37%)* | 6 *(32%)* | **19 *(100%)*** |
| Princeton South | 1 *(10%)* | 1 *(10%)* | 5 *(50%)* | 3 *(30%)* | **10 *(100%)*** |
| Princeton West | 4 *(25%)* | 3 *(19%)* | 5 *(31%)* | 4 *(25%)* | **16 *(100%)*** |
| Princeton East | 2 *(29%)* | – – | 2 *(29%)* | 3 *(43%)* | **7 *(100%)*** |
| **Total** | **14 *(10%)*** | **33 *(24%)*** | **54 *(39%)*** | **38 *(27%)*** | **139 *(100%)*** |

$\chi^2$ (15 df) = 15.58; *p-value* = 0.411

- The "hump" is widely prevalent and found in every part of the continent, even in sub-national regions associated with low childhood mortality.

- It is linked to the high levels of ${}_4q_1$ relative to ${}_1q_0$ observed in Chapter 5 compared with those implied in the Princeton life tables. Tables 6.3 and 6.4 clearly depict that the majority of the schedules with wide humps are associated with the *"Sahelian"* and *"North Plus"* patterns. This is more pronounced in the 1980s, and the situation in the 1990s reveals a few humped schedules classified as Princeton South or West. Notwithstanding this, the "hump" constitutes an integral part of the pattern of childhood mortality in Sub-Saharan Africa.

The fact that such "humps" of excess mortality became more prevalent in Eastern and Southern Africa in the 1990s, coinciding with increases in ${}_5q_0$, is an indication that trends in mortality levels influence mortality pattern through them. Therefore, any attempt to adequately describe or represent the mortality patterns in childhood prevailing in Sub-Saharan Africa, using the Princeton model system alone must prove quite unsuitable.

# Chapter 7

# A Three-Parameter Model of Mortality Patterns within Childhood

## 7.1 Introduction

The major question that still remains to be answered adequately as far as this study is concerned is whether Sub-Saharan Africa is characterised by childhood mortality patterns that are peculiar to the continent. Chapter 5 demonstrated that, on the basis of infant-to-child mortality relationships, more than two-thirds of the sub-national regions considered manifest childhood mortality patterns outside the range of the Princeton model system. However the national surveys were conducted at different dates and this poses problems when it comes to comparing the experiences of adjacent countries. Furthermore, the pattern identification process adopted, as outlined in Chapter 5 (Section 5.2) is subjective in nature, thus presenting a potential for significant errors of judgement to be introduced into the analysis. Thus, although Chapter 5 provides a description of the distribution of childhood mortality patterns in Sub-Saharan Africa based on the relationship of infant and child mortality levels manifested in each sub-national region, the findings need to be supported by statistical evidence as to whether they reflect the prevailing situation in the continent or otherwise.

In addition to the importance of describing patterns of mortality prevalent in Sub-Saharan Africa and their respective characteristics and dynamics as a basis for epidemiological research and general child health policy, a methodological need exists for a life table system more appropriate for use with Brass's indirect technique to estimate under-5 mortality among national and sub-national populations in the continent. In particular, an urgent need exists for new model life tables that encompass ${}_5q_0$ levels ranging from 100 to 350 per 1,000, thus covering all contemporary moderate to high mortality countries in the region. The absence of such models is unfortunate since it is regions like Sub-Saharan Africa — characterised by a paucity of high-quality demographic data — that need such analytic tools most. Yet the limitations of African demographic data remain the greatest challenge in demographers' efforts for the construction of appropriate model life tables that adequately represent prevailing mortality patterns in the continent.

Chapter 6 has demonstrated the existence of a "hump"-like feature in the age-specific childhood mortality schedules for most sub-national regions of the continent. Whether the "hump" is fully responsible for the unusual patterns of mortality identified in Chapter 5 is yet to be established, but it is undoubtedly an important feature of childhood mortality patterns in the continent. The typical mortality schedules prevalent in the countries considered (as presented in Figures 6.9) display a common feature that has not been subjected previously to close scrutiny. In all cases, the age-specific death rates for the ages at the either ends of childhood — i.e. ages 0 and 1-2 months at the lower end, and 24-35, 36-47, and 48-59 months at the upper end — appear to conform to the pattern one would expect from any model life table of the Princeton system. This gives the impression that the identified "humps" represent "excess mortality" between the ages 3 and 23 months relative to a Princeton-type mortality schedule of any family. The significance of this feature of the observed sub-national mortality schedules, as well as the implications it may have for investigation of prevailing mortality patterns in Sub-Saharan Africa, deserves to be assessed thoroughly.

In the light of the foregoing, this chapter sets out to answer the following questions:

i. Is there sufficient evidence in the available database to show that it is the "humps" identified in the mortality schedules of most sub-national regions in the continent that are responsible for the unusual patterns of childhood mortality documented in Chapter 5 as well as in other earlier studies (e.g. Blacker *et al,* 1985; Hill, 1995)?

ii. If the "humps" represent excess mortality within the first two years of life, does controlling for them in a statistical model reveal "underlying" patterns of childhood mortality that fall within or close to the range of the Princeton system?

## 7.2 Data and Methods

The same data derived from the DHS birth histories that were used in the assessment of mortality schedules in childhood in Chapter 6 are used in the ensuing analysis. The same age intervals are adopted; and exposure and death information for the three recent quinquennia prior to each survey are included for each of the 165 sub-national regions. The sum total of the resulting person-years of exposure and deaths for each country are summarised in Table 7.1, giving an indication as to the scale of mortality within childhood for individual countries as well as continental sub-regions. The surveys individually and collectively constitute samples large enough to yield statistically sound and reliable judgements.

Since the ultimate aim is to identify the prevailing patterns of childhood mortality in each of the 165 sub-national regions on the basis of the available information, the analysis adopts a relational approach. This is a procedure whereby attempts are made to describe the mortality patterns of the individual sub-national regions on the basis of a linkage — in the form of a mathematical function — to a known standard mortality pattern. However, the linkage, or "model" as it is usually referred to, has to be constructed to reflect adequately the demographic issues of interest measured quantitatively by specific parameters. An attempt is made to construct an appropriate model in the ensuing sections of the chapter. This is preceded by a description of relational life tables.

### *7.2.1 Relational Models of Mortality*

The review of model life table systems in Chapter 3 (section 3.2) provided an exposition of mathematical and tabular representations of model mortality patterns. It was mentioned that a third approach exists, relational models, which combines features of both mathematical and tabular model life table systems. On the basis of a "standard" age pattern of mortality — usually a well established empirical model life table — a mathematical function is applied to relate the "standard" to the mortality situation of any population. As described by Preston *et al*. (2001), the complexity of age patterns of mortality is captured through the mortality "standard", and the model parameters capture deviations from the "standard". Compared with

**Table 7.1:** ***Summary of person-years of exposure and deaths by country and continental sub-region.***

| **Country** | **No. of Surveys** | **Total Person-Years of Exposure Considered** | **Total Deaths Considered** | **Deaths per 1,000 Person-Years of Exposure** |
|---|---|---|---|---|
| *Sahel West Africa* | | | | |
| Senegal | 3 | 181,436 | 7,633 | 42.07 |
| Mali | 2 | 136,703 | 9,810 | 71.76 |
| Burkina Faso | 2 | 127,090 | 7,021 | 55.24 |
| Niger | 2 | 142,766 | 12,250 | 85.81 |
| *Sub-total* | *9* | *587,995* | *36,714* | *62.44* |
| *Coastal West Africa* | | | | |
| Guinea | 1 | 64,830 | 3,388 | 52.27 |
| Liberia | 1 | 43,002 | 2,807 | 65.29 |
| Côte d'Ivoire | 1 | 75,232 | 2,774 | 36.87 |
| Ghana | 3 | 113,490 | 3,677 | 32.40 |
| Togo | 2 | 107,464 | 4,001 | 37.23 |
| Benin | 1 | 53,119 | 2,496 | 47.00 |
| Nigeria | 2 | 155,649 | 6,306 | 40.51 |
| *Sub-total* | *11* | *612,785* | *25,449* | *41.53* |
| *Middle Africa* | | | | |
| Cameroon | 2 | 79,220 | 2,924 | 36.90 |
| Chad | 1 | 72,553 | 3,807 | 52.48 |
| Central African Rep. | 1 | 49,371 | 1,952 | 39.54 |
| *Sub-total* | *4* | *201,144* | *8,683* | *43.17* |
| *Eastern Africa* | | | | |
| Uganda | 2 | 116,123 | 4,933 | 42.48 |
| Kenya | 3 | 224,749 | 4,996 | 22.23 |
| Rwanda | 1 | 60,455 | 2,688 | 44.46 |
| Burundi | 1 | 35,224 | 1,721 | 48.87 |
| Tanzania | 3 | 184,094 | 7,013 | 38.09 |
| Ethiopia | 1 | 129,023 | 6,377 | 49.42 |
| *Sub-total* | *11* | *749,668* | *27,727* | *36.99* |
| *Southern Africa* | | | | |
| Zambia | 2 | 128,597 | 5,733 | 44.58 |
| Malawi | 1 | 45,260 | 2,884 | 63.72 |
| Mozambique | 1 | 73,324 | 4,075 | 55.57 |
| Zimbabwe | 3 | 131,199 | 2,467 | 18.80 |
| Namibia | 1 | 39,828 | 916 | 23.00 |
| South Africa | 1 | 69,896 | 852 | 12.18 |
| *Sub-total* | *9* | *488,104* | *16,927* | *34.68* |
| ***Total*** | ***44*** | ***2,639,696*** | ***115,500*** | ***43.76*** |

***Sources:*** *Respective National DHS Datasets.*

the purely mathematical or analytical models described in Chapter 3, relational model systems usually require fewer parameters.

Brass (1971; 1975) was the first to propose such a model life table system based on the logit transformation of any of the life table measures $q(x)$ or $l(x)$. More recently, Preston *et al*. (1993) adopted the same technique to construct the New Model Life Tables for High Mortality Populations (see section 3.2.5). Using $q(x)$, for instance, that is the probability of dying by age $x$, the logit transformation, denoted $Y(x)$, is given by

$$Y(x) = \ln\left\{\frac{q(x)}{1-q(x)}\right\}$$

As values of q(x) range from 0 to 1, the values of the resulting transformation therefore are mapped between the range –∞ to +∞ correspondingly. Brass (1971) discovered that the relationship between the logits of the $l(x)$ values of any two life tables is remarkably linear, although the points at the extremes of the age range sometimes fall out of line (Newell, 1988). Thus, if the logits of the $l(x)$ values of an established life table are denoted $Y^s(x)$ and those of a population under investigation by $Y(x)$, then the relationship between the two sets of logits can be expressed algebraically as

$$Y(x) = \alpha + \beta \cdot Y^s(x)$$

Although Brass proposed two main "standard" life tables — i.e. the General and African Standards — any established tabular model life table can be used. The parameters $\alpha$ and $\beta$, i.e. the intercept and gradient of the straight-line relationship between the two sets of logits, represent the level and pattern of mortality respectively relative to the "standard" life table. Varying them yields a wide range of sets of $l(x)$ representing different life tables. A change in $\alpha$ represents a corresponding change in the level of mortality at all ages; whilst $\beta$ measures the relationship between child and adult mortality in an all-age life table.

In the case of childhood mortality analysis, the gradient of the line, $\beta$, represents the relationship between earlier and late mortality relative to the chosen standard, its interpretation in a model fitted for an age range of 0 to 5 years will obviously be completely different. However, the main principles of the relational approach, i.e. the use of an established standard mortality pattern and an application of a mathematical relational function, are adopted to construct a model that is suited to the short age range of interest. In addition to its intended demographic uses, the model is expected to serve the three statistical purposes which, according to Arminger (1995), govern the art of modelling with respect to the outcome of interest — i.e. the pattern of mortality in childhood. These purposes are description, i.e. the process by which the measure of pattern of mortality is generated; inference, i.e. detection of the contribution of each explanatory variable to the prognosis of pattern of mortality; and prediction, i.e. the process of forecasting the measure of pattern of mortality for a specific combination of the values of the explanatory variables.

### *7.2.2 Model Specification*

As shown in Figure 6.3, all four families of the Princeton model system depict trends in age-specific death rates in the form of an exponentially declining curve with increasing age. Assuming that observed sub-national age-specific mortality schedules adopt a similar trend, they can be expressed in terms of one of the Princeton families at a specific level. As in the case of the logit relational approach to survivorship reviewed above, a logarithmic transformation of the sub-national ${}_nm_x$ values should share a linear relationship with those of the corresponding ages in the standard Princeton model, expressed algebraically thus:

$$\ln\left({}_n m_{x[it]}\right) = \alpha_{it} + \beta_{it} \cdot \ln\left({}_n m_x^s\right) \qquad \text{——— (1)}$$

where:

${}_nm_{x[it]}$ is the fitted death rate between exact ages $x$ and $x+n$ in sub-national region $i$ at time $t$;

${}_n m_x^s$ is the death rate for the same age bracket in the standard model life table; and

$\alpha_{it}$ and $\beta_{it}$ are constants unique to region $i$ at specific time $t$ and respectively can be interpreted demographically as the level and age pattern of mortality relative to the chosen standard.

However, it has been demonstrated in Chapter 6 that most sub-national populations of Sub-Saharan Africa — or at least the countries considered here — manifest age-specific mortality schedules in childhood characterised by a deviation from the norm in the form of a "hump" that spans various age brackets within the first two years of life. This departure from the schedule characteristic of the four families of the Princeton model system should therefore be accounted for in the model above represented by equation 1.

Recall that four different average "humps" were identified in the previous chapter. However, as shown in Figures 6.6 and 6.7, the location of the "humps" in terms of start and end points as manifested in the individual sub-national schedules varies widely. Chapter 6 also discussed the potential for the "3rd – 23rd Month Hump" to have resulted in some instances from reporting and sample errors when in reality the population had a narrow "hump" or even a "Princeton Type" mortality schedule. For these reasons, rather than trying to model different types of "hump" it is imperative to restrict the age range affected by the prevalent hump in sub-regional childhood mortality schedules to 6-23 months in the model fitting process. This ensures that three points are fitted on either side of the "hump" thereby safeguarding the reliability of estimates of $\beta_{it}$. Since the middle three age brackets manifest higher death rates relative to the standard, they are accounted for in the model by another level parameter, $\gamma_{it}$, thus yielding

$$\ln\left({}_n m_{x[it]}\right) = \alpha_{it} + \gamma_{it} \cdot X + \beta_{it} \cdot \ln\left({}_n m_x^s\right) \qquad \text{———} \quad (2)$$

where

$$X = \begin{cases} 0 & \text{if } x = 0, \text{1-2, 3-5, 24-35, 36-47, 48-59 months} \\ 1 & \text{if } x = \text{6-8, 9-14, 15-23 months} \end{cases}$$

Recall also that one of the main objectives of this study relates to the determination of the extent of variations in levels and patterns of childhood mortality within and between sub-national regions of the same country as well as between different countries over time. As a result, the model must be designed to capture effects of:

- the characteristics of the region considered,
- time;

- the interaction of time and region, as well as their separate interactions with the age pattern of mortality.

The interpretation of these variable interactions within the context of the model are as follows:

*Region-Time Interaction*

Under ideal conditions, one would expect sub-national regions within a country to be improving economically and socially with time. However, this is not necessarily the case in the many Sub-Saharan African countries that were hit by a wave of economic decline after the 1970s, that was often worsened by inappropriate or wrongly instituted structural adjustment programmes (see Jolly and Cornia, 1984; Cornia *et al.*, 1988). This implies, therefore, that some local regions within certain countries may have witnessed some form of socio-economic development over the recent past and thus improved mortality levels in childhood, but others may have registered significant declines in economic and social services, resulting in worsened mortality conditions with time.

*Pattern-Region Interaction*

This relates to environmental and behavioural factors that tend to influence child survival at specific ages. Infant food supplementation methods and weaning practices, for instance, vary from one region to another, thus having different impacts on age-specific death rates in childhood. Also certain diseases are more prevalent in some regions than in others, and since illness recovery levels are determined in part by level of social and economic advancement at the local regional level, different age-specific death rates are expected to differ between regions.

*Pattern-Time Interaction*

Generally, according to the demographic literature, age-specific death rates are expected to fall over time. More significant improvements are probably occurring for certain ages than others. Therefore, age-specific death rates may be lower for recent calendar periods than for periods further back in the past. However, it should be noted that the reverse may also hold in countries where evidence has shown recent increases in childhood mortality.

Assuming that all the determinants of level, pattern and intensity of the hump in the age-specific mortality schedule of sub-national region *i* relative to the chosen standard are captured by time, *t*, and the uniqueness of the region in terms of its socio-cultural, economic, environmental and demographic characteristics, then the constituents of the parameters $\alpha_{it}$, $\gamma_{it}$, and $\beta_{it}$ can be represented as:

$$\alpha_{it} = \lambda_0 + \lambda_i + \lambda_t + \lambda_T + \lambda_{t \cdot i} + \lambda_{T \cdot i} \qquad \text{——— (3)}$$

$$\beta_{it} = \lambda_p + \lambda_{p \cdot i} + \lambda_{p \cdot t} + \lambda_{p \cdot T} + \lambda_{p \cdot t \cdot i} + \lambda_{p \cdot T \cdot i} \qquad \text{——— (4)}$$

$$\gamma_{it} = \lambda_h + \lambda_{h \cdot i} + \lambda_{h \cdot t} + \lambda_{h \cdot T} + \lambda_{h \cdot t \cdot i} + \lambda_{h \cdot T \cdot i} \qquad \text{——— (5)}$$

$\lambda_0$ — Base risk of dying at any age in any region, *i*, of a country and at any time, *t*;
$\lambda_i$ — Risk of dying due to the effect of the characteristics of the region;
$\lambda_t$ — Risk of dying due to the effect of time;
$\lambda_T$ — Risk of dying due to the effect of the square of time;
$\lambda_{t \cdot i}$ — Risk of dying due to the interaction effect of region and time;
$\lambda_{T \cdot i}$ — Risk of dying due to the interaction effect of region and the square of time.

$\lambda_p$ — Base indicator of mortality pattern in any region, *i*, of a country and at any time, *t*;
$\lambda_{p \cdot i}$ — Effect on pattern due to the characteristics of the region;
$\lambda_{p \cdot t}$ — Effect on pattern due to time;
$\lambda_{p \cdot T}$ — Effect on pattern due to the square of time;
$\lambda_{p \cdot t \cdot i}$ — Effect on pattern due to the interaction between region and time;
$\lambda_{p \cdot T \cdot i}$ — Effect on pattern due to the interaction between region and the square of time.

The descriptions of the constituents of the "hump" parameter, $\gamma_{it}$, are similar to those for $\beta_{it}$.

Since the age-specific death rates in region *i* at time *t* are given by the ratios of the corresponding deaths, $D_{x[it]}$, to person years of exposure, $E_{x[it]}$, then the model as represented by equation 2 can be restated as:

$$\ln\left(D_{x[it]}\right) - \ln\left(E_{x[it]}\right) = \alpha_{it} + \gamma_{it} \cdot X + \beta_{it} \cdot \ln\left({}_n m_x^s\right) \quad \text{———} \quad (6)$$

Considering the fact that an underlying risk of dying in any region and at any age and time is assumed, the model can be estimated using Poisson regression with $\ln(E_{x[it]})$ as an "offset". The relevant parameters are therefore estimated using Poisson regression. The model is fitted to each of the 26 six countries in turn for the following reasons:

a. To enable the identification of country or survey biases when all the results are pooled together and cross-border comparisons made.

b. Merging all country datasets and fitting a model for 165 regions is beyond the capacity of the software application, STATA, and would prove to be cumbersome anyway even if it were possible.

### *7.2.3 Selection of Standard Model Pattern of Mortality*

The selection of a standard model pattern focuses on the level of infant mortality. Observed national levels of infant mortality (as indicated in Chapter 4) can be compared with those indicated by model life tables. Using only the DHS datasets included in this study, the highest observed level of ${}_1q_0$ is 142 per 1,000 live births in Liberia in 1984; and the lowest is 39.2 per 1,000 live births in South Africa in 1996. The mid-point between these two extreme levels of infant mortality is 90.65 per 1,000, and the mean of the most recent levels of infant mortality in all the countries included in the study is also 90.4 per 1,000 live births.

In order to capture the effects of the biological factors on infant mortality especially, an average pattern of Princeton "North" level 15 for both sexes with a sex ratio at birth of 1.03 is adopted as the standard in the modelling process. The detailed age-specific death rates characteristic of this model life table are determined by interpolation using the Brass and Blacker (1999) approach described in Chapter 5. These rates are presented in Appendix 4.

### *7.2.4 Modelling the Trend in Mortality*

Time, in the form of calendar year, is included in the model as a continuous variable in the form of a number of years from a specific reference date. Any calendar year could be chosen as reference date without having any impact on the results but using different dates for different countries will make comparison of results a rather tedious process. One date that falls within the fifteen-year span of all 44 datasets is 1985. Since this particular year also happens to broadly represent the onset of the impact of the AIDS epidemic in the continent, it was therefore adopted as the model reference date.

The respective model parameters include $T$, the square of time. This enables the model to capture recent increases in childhood mortality in countries where evidence of this exists. On the basis of the trends of childhood mortality presented in Chapter 4, the variable is not included in models fitted to data from Western and Middle Africa. In Eastern and Southern African countries, the inclusion of second order time and time-related interaction variables is solely on the basis of statistical significance. Assuming a quadratic trend tends to distort the fitted values especially at extreme time points, but fitting more flexible models sometimes produces even less plausible results.

### *7.2.5 Demographic Implications of the Model*

Figure 7.1 graphically explains what the parameters of the model indicate. A $\beta$-value of 1 represents a reproduction of the Princeton "North" pattern. The more its value increases beyond unity, the steeper the line that relates it to the standard "North" pattern, implying low mortality in later childhood relative to infancy. Conversely, the lower $\beta$ drops below 1, the gentler the slope, implying higher death rates in later childhood relative to the youngest ages. The unusual patterns of childhood mortality identified earlier in Chapter 5 are characterised by low values of $\beta$.

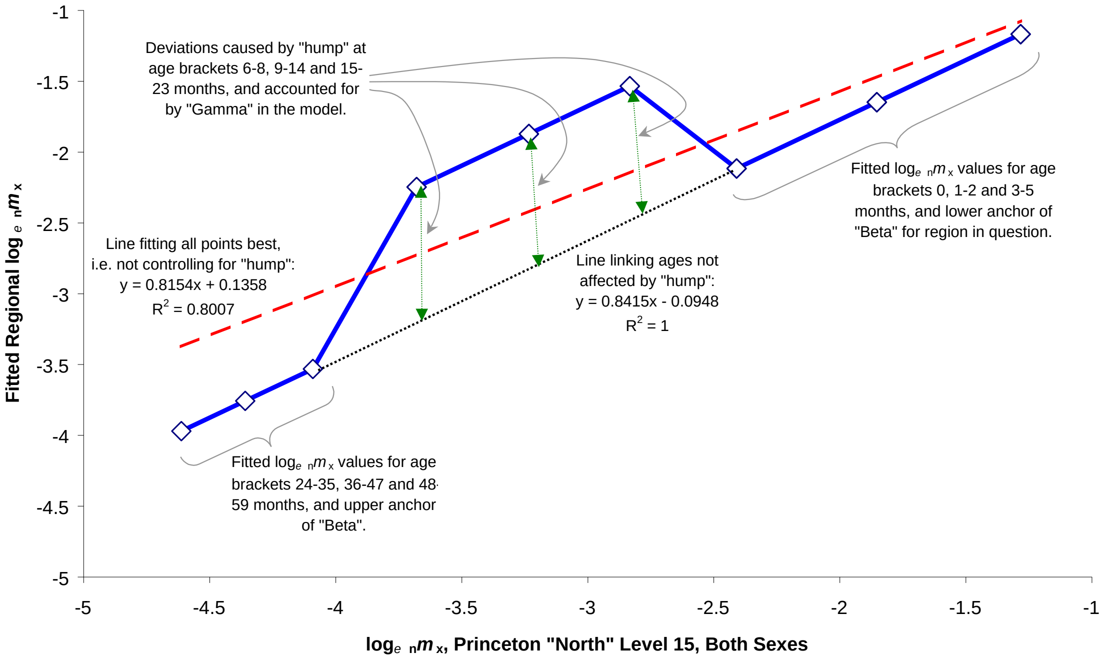



**Figure 7.1:** ***Graphical demonstration of model as fitted to a specific region at a specific point in time.***

An attempt to fit a relational model without controlling for the effect of the “hump”, i.e. without $\gamma$, will yield a low value of $\beta$ because of the greater weighting given to points calculated from more deaths as indicated by the broken line in Figure 7.1. This results in a fitted model implying higher death rates in the older ages relative to the standard chosen. Most importantly, it conceals the “underlying” pattern of mortality in childhood as reflected by the age brackets between birth and 5 months on one hand, and between 24 and 59 months on the other.

In order to get an indication as to what range of $\beta$-values from the model the other Princeton families might cover, the logarithm of their interpolated ${}_nm_x$ values presented in Appendix 4 were regressed against those of the “North” model using ordinary least squares. The values of the respective parameters of level and pattern are shown in Table 7.2. On the basis of the $\beta$-values obtained, the range that each family is thought to cover was computed by a chain process of adding half the difference of the values of two families to the value of the latter, and rounded up to the nearest neat figure. This yielded the ranges defined in Table 7.3.

**Table 7.2:** ***Parameters obtained from a demonstration of model fitting procedure using Princeton "North" Level 15 for both sexes as standard on the life tables of the other families at the same level.***

| **Life Table** | $\alpha$ | $\beta$ | $R^2$ |
|---|---|---|---|
| "**South**" Level 15, Both Sexes | 0.6891 | 1.1914 | 0.9859 |
| "**West**" Level 15, Both Sexes | 0.6405 | 1.2554 | 0.9959 |
| "**East**" Level 15, Both Sexes | 1.1301 | 1.4019 | 0.9841 |

**Table 7.3:** ***Estimated ranges of β-Values covered by the Princeton families of model mortality patterns.***

| **Pattern** | **Range of β-Values Estimated to Cover** |
|---|---|
| More extreme than Princeton "North" | ≤ 0.900 |
| Princeton "North" | 0.901 — 1.100 |
| Princeton "South" | 1.101 — 1.225 |
| Princeton "West" | 1.226 — 1.325 |
| Princeton "East" | 1.325 — 1.475 |
| More extreme than Princeton "East" | > 1.475 |

## 7.3 Results

### *7.3.1 "Underlying" Patterns of Mortality in Childhood*

The constituents of each national model that collectively represent the pattern of mortality at both country and sub-national regional levels are presented in Tables 7.4 – 7.8 by sub-region of the continent. Those that constitute level of mortality relative to the standard and the measure of the intensity of the "mortality hump" between ages 6 and 23 months (if any exists) are similarly presented in Appendices 6 and 7 respectively.

The results of the model fitting procedure as applied to the Princeton families and presented in Table 7.2 constitute a useful guide to the interpretation of the results of the individual country models. In conjunction with the background information provided in Chapter 5 about the distribution of Princeton-type childhood mortality patterns across the continent (albeit based only on the infant-to-child mortality relationship points), one can quickly identify national and sub-national patterns that are significantly different from what is expected. The results are presented starting with the sub-continental region believed to be characterised by Princeton-type patterns of mortality in childhood, i.e. Southern Africa, and proceeding north and north-westwards to the Sahel West African region. It should be recalled that the indicators of pattern resulting from the fitted models relate to mortality schedules in childhood purged of the "hump" of excess mortality. Within the context of the analysis in this section, therefore, the $\beta$-values represent such "underlying" childhood mortality patterns in the respective national and sub-national regions.

Table 7.4 shows the estimates of $\beta$ in each of the six southern African countries considered. The national $\beta$-values, i.e. the value of $\lambda_p$ in 1985 (when $t = 0$) at the level of the country (shown in bold), indicate mortality patterns in childhood that are less extreme[5] than those of the Princeton "North" models since all values are greater than 1. In fact, Zimbabwe, Namibia and South Africa display national $\beta$-values that indicate childhood mortality patterns more extreme than those in the Princeton "East" models. These are therefore characterised by very low age-specific death rates in the older ages of childhood relative to the period of infancy. Zambia and Malawi have national $\beta$-values that fall within the range of the "South" pattern of mortality, whilst that of Mozambique reflects the "East" pattern. With respect to variations in $\beta$ over time, the Zambian and Malawian country models yielded a statistically significant positive coefficients at the national level — $p \leq 0.01$ and $p \leq 0.1$ respectively. However, Mozambique and Namibia depict slightly reducing values of $\beta$ at rates of about 0.0008 and 0.0042 per annum respectively from 1985.

[5] This description refers to the distribution of the ${}_1q_0$-to-${}_4q_1$ relationship points as they compare with the standard distributions among the Princeton families as used in the analysis presented in Chapter 5.

**Table 7.4:** ***Regression coefficients determining the nature of and explaining national and sub-national variations in childhood mortality pattern in Southern Africa relative to Princeton "North" Level 15 for both sexes.***

| **Country** | $\beta_i$ | | | |
|---|---|---|---|---|
| **Region** | $\lambda_p^*$ | $\lambda_{pi}$ | $\lambda_{pti}$ | $R^2$ |
| ***SOUTHERN AFRICA*** | | | | |
| **Zambia** | **1.2094 *(0.0193)*** | | **0.0094*** ***(0.0036)*** | **0.6663** |
| *Sub-national regions* | 1.1643 *(0.0544)* | | 0.0084 *(0.0103)* | 0.7101 |
| Zambia Central | | -0.0207 *(0.0854)* | 0.0311‡ *(0.0169)* | |
| Copperbelt | | -0.1005 *(0.0714)* | 0.0037 *(0.0132)* | |
| Zambia Eastern | | 0.0295 *(0.0716)* | 0.0120 *(0.0138)* | |
| Luapula | | 0.1160 *(0.0830)* | -0.0095 *(0.0153)* | |
| Lusaka | | 0.0757 *(0.0782)* | -0.0051 *(0.0142)* | |
| Zambia Northern | | — | — | |
| Zambia North-Western | | 0.1316 *(0.1255)* | -0.0136 *(0.0232)* | |
| Zambia Southern | | 0.1225 *(0.0814)* | -0.0132 *(0.0151)* | |
| Zambia Western | | 0.1766† *(0.0857)* | 0.0048 *(0.0164)* | |
| **Malawi** | **1.1297 *(0.0214)*** | | **0.0098‡ *(0.0053)*** | **0.7835** |
| *Sub-national regions* | 1.2214 *(0.0693)* | | 0.0056 *(0.0172)* | 0.8040 |
| Malawi North | | — | — | |
| Malawi Central | | -0.2713* *(0.0758)* | 0.0081 *(0.0187)* | |
| Malawi South | | 0.0728 *(0.0771)* | 0.0012 *(0.0191)* | |
| **Zimbabwe** | **1.5201 *(0.0291)*** | | **0.0011 *(0.0044)*** | **0.5991** |
| *Sub-national regions* | 1.4924 *(0.0697)* | | -0.0138 *(0.0095)* | 0.6270 |
| Manicaland | | — | — | |
| Mashonaland Central | | -0.0962 *(0.1124)* | 0.0588* *(0.0176)* | |
| Mashonaland East | | -0.1853‡ *(0.1015)* | 0.0360† *(0.0149)* | |
| Mashonaland West | | 0.1680 *(0.1113)* | -0.0038 *(0.0166)* | |
| Matabeleland North | | 0.0913 *(0.1513)* | 0.0121 *(0.0242)* | |
| Matabeleland South | | 0.6211* *(0.2008)* | 0.0350 *(0.0305)* | |
| Zimbabwe Midlands | | 0.1354 *(0.1079)* | 0.0058 *(0.0153)* | |
| Masvingo | | -0.1338 *(0.1024)* | 0.0379† *(0.0161)* | |
| Harare Chitungwiza | | 0.1787 *(0.1483)* | -0.0256 *(0.0188)* | |
| Bulawayo | | 0.4290† *(0.2193)* | -0.0002 *(0.0282)* | |
| **Mozambique** | **1.3202 *(0.0331)*** | | **-0.0008 *(0.0049)*** | **0.6953** |
| *Sub-national regions* | 1.4661 *(0.1599)* | | -0.0296 *(0.0226)* | 0.7485 |
| Niassa | | -0.2257 *(0.1978)* | 0.0250 *(0.0287)* | |
| Cabo Delgado | | 0.4416‡ *(0.2646)* | -0.0469 *(0.0346)* | |
| Nampula | | 0.2095 *(0.1775)* | -0.0003 *(0.0249)* | |
| Zambezia | | -0.4289† *(0.1783)* | 0.0687* *(0.0256)* | |
| Tete | | -0.4488† *(0.1904)* | 0.0539‡ *(0.0282)* | |
| Manica | | — | — | |
| Sofala | | -0.4114† *(0.1757)* | 0.0561† *(0.0249)* | |
| Inhambane | | 0.0527 *(0.2060)* | 0.0247 *(0.0298)* | |
| Gaza | | -0.2662 *(0.1935)* | 0.0203 *(0.0273)* | |
| Maputo | | -0.3312 *(0.2285)* | 0.0687† *(0.0330)* | |
| Cidade de Maputo | | 0.2237 *(0.2721)* | -0.0489 *(0.0369)* | |

** $p < 0.01$ for all coefficients of $\lambda_p$. * $p \leq 0.01$; † $p \leq 0.05$; ‡ $p \leq 0.1$. Standard Errors are in parentheses; — denotes reference region.*

**Table 7.4 *(cont'd)***

| Country | $\beta_i$ | | | |
|---|---|---|---|---|
| Region | $\lambda_p^*$ | $\lambda_{pi}$ | $\lambda_{pti}$ | $R^2$ |
| ***SOUTHERN AFRICA (cont'd)*** | | | | |
| **Namibia** | **1.5208 *(0.0431)*** | | **-0.0042 *(0.0105)*** | **0.7057** |
| *Sub-national regions* | 1.5688 *(0.0706)* | | -0.0032 *(0.0171)* | 0.7309 |
| Namibia Northwest | | — | — | |
| Namibia Northeast | | -0.2273† *(0.1042)* | 0.0099 *(0.0254)* | |
| Namibia Central | | -0.1586 *(0.1489)* | -0.0287 *(0.0356)* | |
| Namibia South | | 0.1689 *(0.1233)* | 0.0101 *(0.0303)* | |
| **South Africa** | **1.7179 *(0.0867)*** | | **0.0049 *(0.0121)*** | **0.6773** |
| *Sub-national regions* | 1.5923 *(0.1816)* | | 0.0431 *(0.0291)* | 0.7390 |
| Western Cape | | 2.2118† *(1.0565)* | -0.1602 *(0.1642)* | |
| Eastern Cape | | — | — | |
| Northern Cape | | 0.3163 *(0.7790)* | -0.0798 *(0.0934)* | |
| Free State | | -0.0137 *(0.4027)* | -0.0450 *(0.0556)* | |
| KwaZulu Natal | | -0.1013 *(0.2331)* | -0.0383 *(0.0353)* | |
| South Africa North West | | -0.1887 *(0.2884)* | -0.0218 *(0.0476)* | |
| Gauteng | | 1.7858* *(0.5130)* | -0.1623* *(0.0611)* | |
| Mpumalanga | | -0.0627 *(0.3068)* | -0.0068 *(0.0500)* | |
| Northern Province | | 0.4256 *(0.3688)* | -0.0707 *(0.0490)* | |

** $p < 0.01$ for all coefficients of $\lambda_p$. * $p \leq 0.01$; † $p \leq 0.05$; ‡ $p \leq 0.1$. Standard Errors are in parentheses; — denotes reference region.*

At the sub-national level, substantial variations in $\beta$ are observed in Zimbabwe and Mozambique. Bulawayo and Matabeleland South, for instance, were significantly different from the other Zimbabwean regions in 1985 as far as childhood mortality patterns are concerned. In a similar way, the regions of Zambezia, Tete and Sofala differed from the rest of Mozambique; and Malawi Central and Zambia Western stood conspicuous in their respective countries. Some differential trends in $\beta$ are observed at the sub-national level. Mozambique manifested more sub-national variation in annual rates of change in $\beta$ than any other country in this zone of the continent. No evidence was found of differential trends in $\beta$ in Malawi and Namibia.

In the models fitted for Eastern African countries, time-square ($T$) related parameters were found to be significant in Uganda, Kenya and Tanzania. In the case of Uganda, the statistical significance was limited to the level of the country only. $R^2$ is more than 0.75 for all national and sub-national models fitted except in the cases of Rwanda and Burundi, whose models registered $R^2$ values of 0.67 and 0.62 respectively (see Table 7.6), and the Kenyan national model. The six countries considered in this part of the continent display national $\beta$-values that range from 1.0604 in Burundi to 1.4458 in Kenya — a wide spectrum encompassing all four Princeton families of model mortality patterns. Kenya is the only country with a national $\beta$ high enough to fall within the range of the Princeton "East" pattern in 1985, whilst Tanzania's value suggests a pattern between "West" and "East" but closer to "West". Similarly, Uganda's $\beta$-value of 1.2828 correlates to a "West" pattern of childhood mortality; while Rwanda and Burundi had patterns in 1985 more like those in the Princeton "South" and "North" models respectively. Ethiopia's value falls between "South" and "West", but closer to "South". Therefore, all Eastern African countries can be said to have displayed national childhood mortality patterns in 1985 that fall within the Princeton range. Annual rates of change in $\beta$ were significant in Tanzania ($p \leq 0.01$) and Rwanda ($p \leq 0.05$) with $\beta$ increasing with time in both countries.

As at the model reference date, statistically significant differentials in $\beta$ existed at the sub-national level of every Eastern African country (excluding Rwanda and Burundi that are modelled as single regions). In Uganda, the Northern and Western Regions differed from the other two regions, with the former having a significantly lower $\beta$ and the latter a significantly higher one. This implies much higher $_4q_1$ in the northern part of the country in 1985 than in any other region. The same description can be extended to the cases of the Coast and Western Regions of Kenya for the same period, with Western Region displaying the highest levels of age-specific death rates in the older ages of childhood relative to the younger ages. In Tanzania, it is the north-eastern regions of Coast and Northern Highlands that differed markedly from the rest of the country. In Ethiopia, the northern region of Affar apparently has a very low $\beta$ that implies a more extreme mortality schedule than in the Princeton "North" models (see Table 7.5).

With respect to variations in $\beta$ over time, the Tanzanian regions presented the most dynamic scenario. The northern regions of Coast and Northern Highlands and the southern regions of Tanzania South and Southern Highlands display similar features in terms of the effects of their model constituents of $\lambda_{pti}$ and $\lambda_{pTi}$. Significant time variations in $\beta$ are also displayed by Central, Coastal and Western Regions of Kenya; Northern Uganda; and the region of Oromiya in Ethiopia.

**Table 7.5:** ***Regression coefficients determining the nature of and explaining national and sub-national variations in childhood mortality pattern in Eastern Africa relative to Princeton "North" Level 15 for both sexes.***

| Country / Region | $\beta_i$: $\lambda_p^*$ | $\lambda_{pi}$ | $\lambda_{pti}$ | $\lambda_{pTi}$ | $R^2$ |
|---|---|---|---|---|---|
| ***EASTERN AFRICA*** | | | | | |
| **Uganda** | **1.2828 *(0.0223)*** | | **0.0022 *(0.0034)*** | **-0.0012$^{\dagger}$ *(0.0005)*** | **0.7493** |
| *Sub-national regions* | 1.2477 *(0.0358)* | | -0.0002 *(0.0067)* | -0.0014$^{*}$ *(0.0005)* | 0.7628 |
| Uganda Central | | — | — | | |
| Uganda Eastern | | 0.0532 *(0.0471)* | 0.0010 *(0.0092)* | | |
| Uganda Northern | | -0.1217$^{\dagger}$ *(0.0549)* | 0.0215$^{\dagger}$ *(0.0109)* | | |
| Uganda Western | | 0.1347$^{*}$ *(0.0473)* | 0.0013 *(0.0092)* | | |
| **Rwanda** | **1.1725 *(0.0329)*** | | **0.0111$^{\dagger}$ *(0.0051)*** | **-0.0033$^{\dagger}$ *(0.0016)*** | **0.6744** |
| **Burundi** | **1.0604 *(0.0409)*** | | **0.0098 *(0.0067)*** | | **0.6240** |
| **Kenya** | **1.4458 *(0.0193)*** | | **0.0039 *(0.0031)*** | **-0.0010$^{*}$ *(0.0002)*** | **0.6631** |
| *Sub-national regions* | 1.4690 *(0.0625)* | | -0.0056 *(0.0096)* | 0.0017 *(0.0015)* | 0.7644 |
| Nairobi | | -0.1722 *(0.1288)* | -0.0028 *(0.0219)* | -0.0021 *(0.0030)* | |
| Kenya Central | | 0.2496 *(0.1247)* | 0.0205 *(0.0163)* | -0.0048$^{\ddagger}$ *(0.0026)* | |
| Kenya Coast | | 0.1071$^{\dagger}$ *(0.1017)* | 0.0293$^{\dagger}$ *(0.0136)* | -0.0046$^{\dagger}$ *(0.0022)* | |
| Kenya Eastern | | — | — | — | |
| Nyanza | | -0.0612 *(0.0752)* | 0.0082 *(0.0116)* | -0.0025 *(0.0017)* | |
| Rift Valley | | 0.1688$^{\ddagger}$ *(0.0904)* | 0.0074 *(0.0136)* | -0.0029 *(0.0020)* | |
| Kenya Western | | -0.1787$^{\dagger}$ *(0.0813)* | 0.0155 *(0.0120)* | -0.0062$^{*}$ *(0.0018)* | |
| **Tanzania** | **1.3217 *(0.0169)*** | | **0.0078$^{*}$ *(0.0029)*** | | **0.7415** |
| *Sub-national regions* | 1.2889 *(0.0304)* | | 0.0234$^{*}$ *(0.0065)* | -0.0013 *(0.0008)* | 0.7658 |
| Tanzania Coastal | | 0.0905$^{\ddagger}$ *(0.0507)* | -0.0441$^{*}$ *(0.0109)* | 0.0041$^{*}$ *(0.0012)* | |
| Tz Northern Highlands | | 0.2012$^{\dagger}$ *(0.0908)* | -0.0507$^{\dagger}$ *(0.0201)* | 0.0051$^{*}$ *(0.0020)* | |
| Lake | | — | — | — | |
| Tanzania Central | | -0.0057 *(0.0614)* | 0.0046 *(0.0129)* | -0.0007 *(0.0015)* | |
| Tz Southern Highlands | | -0.0184 *(0.0576)* | -0.0333$^{*}$ *(0.0125)* | 0.0024$^{\ddagger}$ *(0.0014)* | |
| Tanzania South | | -0.0141 *(0.0643)* | -0.0227$^{\ddagger}$ *(0.0134)* | 0.0032$^{\dagger}$ *(0.0016)* | |
| **Ethiopia** | **1.2207 *(0.0305)*** | | **0.0010 *(0.0035)*** | | **0.7679** |
| *Sub-national regions* | 1.2429 (0.0627) | | -0.0121$^{\ddagger}$ *(0.0071)* | | 0.7802 |
| Tigray | | 0.0668 *(0.1430)* | 0.0124 *(0.0162)* | | |
| Affar | | -0.5703$^{\dagger}$ *(0.2357)* | 0.0451 *(0.0283)* | | |
| Amhara | | 0.2209$^{\dagger}$ *(0.0911)* | -0.0032 *(0.0102)* | | |
| Oromiya | | -0.1734$^{\dagger}$ *(0.0783)* | 0.0288$^{*}$ *(0.0090)* | | |
| Somali | | -0.3465 *(0.2668)* | 0.0420 *(0.0319)* | | |
| Ben-Gumz | | 0.1107 *(0.2777)* | -0.0195 *(0.0307)* | | |
| SNNP | | — | — | | |
| Gambela | | -0.2475 *(0.5568)* | 0.0207 *(0.0644)* | | |
| Harari | | 0.0198 *(0.6833)* | 0.0080 *(0.0782)* | | |
| Addis | | 0.5603 *(0.4478)* | -0.0023 *(0.0483)* | | |
| Dire Dawa | | 0.3896 *(0.6282)* | -0.0275 *(0.0671)* | | |

*$^{*}$ $p < 0.01$ for all coefficients of $\lambda_p$. $^{*}$ $p \leq 0.01$; $^{\dagger}$ $p \leq 0.05$; $^{\ddagger}$ $p \leq 0.1$. Standard Errors are in parentheses; — denotes reference region.*

The results for the three Middle African countries presented in Table 7.6 show $R^2$ values of at least 0.63 for national and sub-national models; and national $\beta$-values of more than unity in all cases. The figures for Chad, Cameroon and Central African Republic indicate national “underlying” patterns of Princeton "South", “West” and “East” respectively for the year 1985. Cameroon presents a near homogeneous pattern of mortality across the country because neither were its regions significantly different each other in 1985 nor were the rates at which $\beta$ changes with time. Notwithstanding this, a statistically significant fall in $\beta$ is occurring ($p \leq 0.01$). Whilst only Mayo-Kebi and Tandjile appear different from the rest of Chad at the model reference date, the regions of the Central African Republic display differences of varying degrees from the $\beta$ levels of Health Regions II and III. Only Health Region I shows a significant reduction in $\beta$ over time. Salamat and Tandjile Regions in Chad display similar significant rates of decline, while a much more significant rate of increase in $\beta$ occurs in the region of Bilitine.

Models fitted for Coastal West African countries yielded $R^2$ values of more than 0.60 except for Ghana, which displayed a value of 0.5396 for its national model and 0.5768 for the fitted sub-national models. The highest figure obtained was 0.86 for Liberia. National $\beta$-values obtained range from a low of 1.0128 in Benin to a high of 1.4975 in Liberia (see Table 7.7). These values imply with childhood mortality patterns that are Princeton “North” in the case of Benin; “South” but near to the “North” pattern for Guinea, Togo and Nigeria; “West” and “East” for neighbours Ghana and Côte d’Ivoire respectively; and a pattern of mortality more extreme than Princeton “East” in Liberia. $\beta$ has been rising in Guinea and Benin but falling in Cote d'Ivoire.

With respect to sub-national variations in $\beta$ at the model reference date, Guinea and Liberia are homogeneous like Cameroon in Middle Africa, save that the rates of increase with time are significant for Upper and Forest Guinea. In Côte d’Ivoire, the North and Centre East Regions show $\beta$-values at opposite ends of the spectrum and appear distinctly different from all other regions of the country. Ghana’s Northern and Upper West Regions had much lower levels of $\beta$ in 1985 than any of the country’s sub-national regions; whereas the Togolese regions of Maritime and de la Kara displayed significantly high and low $\beta$-values respectively

**Table 7.6:** ***Regression coefficients determining the nature of and explaining national and sub-national variations in childhood mortality pattern in Middle Africa relative to Princeton "North" Level 15 for both sexes.***

| **Country** / **Region** | $\beta_i$: $\lambda_p^*$ | $\beta_i$: $\lambda_{pi}$ | $\beta_i$: $\lambda_{pti}$ | $R^2$ |
|---|---|---|---|---|
| ***MIDDLE AFRICA*** | | | | |
| **Cameroon** | **1.2926** ***(0.0266)*** | | **-0.0171*** ***(0.0041)*** | **0.6357** |
| *Sub-national regions* | 1.2590 *(0.0343)* | | -0.0155* *(0.0055)* | 0.6927 |
| North/Adamawa | | — | — | |
| Central/South/East | | 0.0972 *(0.0719)* | -0.0122 *(0.0107)* | |
| West/Littoral | | 0.0411 *(0.0855)* | 0.0105 *(0.0135)* | |
| Northwest/Southwest | | 0.0413 *(0.0894)* | -0.0025 *(0.0136)* | |
| **Central African Republic** | **1.3662** ***(0.0359)*** | | **-0.0057** ***(0.0068)*** | **0.7426** |
| *Sub-national regions* | 1.2084 *(0.0700)* | | 0.0091 *(0.0138)* | 0.7659 |
| CAR Health Region I | | 0.2772† *(0.1090)* | -0.0344‡ *(0.0202)* | |
| CAR Health Region II | | 0.0315 *(0.1003)* | -0.0057 *(0.0196)* | |
| CAR Health Region III | | — | — | |
| CAR Health Region IV | | 0.2921† *(0.1462)* | -0.0208 *(0.0286)* | |
| CAR Health Region V | | 0.3697* *(0.1438)* | 0.0069 *(0.0284)* | |
| Bangui | | 0.2237‡ *(0.1198)* | -0.0342 *(0.0233)* | |
| **Chad** | **1.1688** ***(0.0306)*** | | **0.0011** ***(0.0046)*** | **0.6358** |
| *Sub-national regions* | 1.0613 *(0.1473)* | | 0.0233 *(0.0253)* | 0.6755 |
| Batha | | — | — | |
| Borkou-Ennedi-Tibesti | | -0.0633 *(0.3921)* | -0.0404 *(0.0629)* | |
| Bilitine | | -0.1595 *(0.2281)* | 0.1024† *(0.0445)* | |
| Chari-Baguirmi | | 0.0483 *(0.1694)* | -0.0150 *(0.0283)* | |
| Guéra | | -0.0737 *(0.1917)* | 0.0039 *(0.0327)* | |
| Kanem | | -0.2532 *(0.1882)* | -0.0214 *(0.0309)* | |
| Lac | | 0.2845 *(0.2956)* | -0.0275 *(0.0421)* | |
| Logone Occidental | | 0.0676 *(0.1927)* | 0.0310 *(0.0341)* | |
| Logone Oriental | | 0.2059 *(0.1783)* | -0.0248 *(0.0295)* | |
| Mayo-Kébbi | | 0.5272* *(0.1859)* | -0.0630 *(0.0301)* | |
| Moyen Chari | | 0.2354 *(0.1839)* | -0.0340 *(0.0297)* | |
| Ouaddaï | | -0.1500 *(0.1691)* | -0.0059 *(0.0285)* | |
| Salamat | | 0.2096 *(0.2134)* | -0.0559‡ *(0.0338)* | |
| Tandjilé | | 0.3323‡ *(0.1821)* | -0.0501‡ *(0.0294)* | |
| N'Djamena | | 0.1037 *(0.1942)* | -0.0310 *(0.0308)* | |

** p < 0.01 for all coefficients of $\lambda_p$. * $p \leq 0.01$; † $p \leq 0.05$; ‡ $p \leq 0.1$. Standard Errors are in parentheses; — denotes reference region.*

relative to Togo Centrale Region. In neither Ghana nor Togo was any region's rate of change in $\beta$ significantly different from those of the rest of the country. Mono and Zou Regions displayed the lowest $\beta$-values in 1985 in Benin, but the rate of increase in the case of Mono is more rapid than elsewhere ($p \leq 0.05$). And finally, Nigeria's Central and southern regions

**Table 7.7:** ***Regression coefficients determining the nature of and explaining national and sub-national variations in childhood mortality pattern in Coastal West Africa relative to Princeton "North" Level 15 for both sexes.***

| **Country** | | $\beta_i$ | | |
|---|---|---|---|---|
| **Region** | $\lambda_p^*$ | $\lambda_{pi}$ | $\lambda_{pti}$ | $R^2$ |
| ***COASTAL WEST AFRICA*** | | | | |
| **Guinea** | **1.1660 *(0.0408)*** | | **0.0087‡ *(0.0050)*** | **0.7474** |
| *Sub-national regions* | 1.1819 *(0.0881)* | | -0.0100 *(0.0105)* | 0.7663 |
| Lower Guinea | | — | — | |
| Central Guinea | | 0.0270 *(0.1220)* | 0.0185 *(0.0150)* | |
| Upper Guinea | | -0.0756 *(0.1245)* | 0.0268‡ *(0.0151)* | |
| Forest Guinea | | -0.0751 *(0.1189)* | 0.0322† *(0.0144)* | |
| Conakry | | 0.1403 *(0.1738)* | 0.0032 *(0.0203)* | |
| **Liberia** | **1.4975 *(0.0433)*** | | **-0.0020 *(0.0065)*** | **0.8626** |
| *Sub-national regions* | 1.6757 *(0.2603)* | | -0.0056 *(0.0377)* | 0.8689 |
| Sinoe | | — | — | |
| Grand Gedeh | | -0.3006 *(0.2999)* | 0.0061 *(0.0434)* | |
| Montserrado | | -0.2782 *(0.2733)* | -0.0028 *(0.0398)* | |
| Rest of Liberia | | -0.1321 *(0.2661)* | 0.0062 *(0.0385)* | |
| **Côte d'Ivoire** | **1.4475 *(0.0297)*** | | **-0.0129† *(0.0059)*** | **0.7039** |
| *Sub-national regions* | 1.3974 *(0.1113)* | | 0.0168 *(0.0235)* | 0.7280 |
| CI Centre | | — | — | |
| CI Centre North | | 0.2955‡ *(0.1693)* | -0.0181 *(0.0357)* | |
| CI North East | | -0.1072 *(0.1645)* | -0.0238 *(0.0350)* | |
| CI Centre East | | -0.5264* *(0.1843)* | 0.0664‡ *(0.0379)* | |
| CI South | | 0.0386 *(0.1249)* | -0.0373 *(0.0261)* | |
| CI South West | | 0.1319 *(0.1737)* | -0.0502 *(0.0344)* | |
| CI Centre West | | -0.0868 *(0.1282)* | -0.0128 *(0.0270)* | |
| CI West | | 0.1983 *(0.1439)* | -0.0630† *(0.0290)* | |
| CI West | | -0.0365 *(0.1669)* | -0.0434 *(0.0334)* | |
| CI North | | 0.4393* *(0.1714)* | -0.0405 *(0.0347)* | |
| **Ghana** | **1.2544 *(0.0194)*** | | **-0.0033 *(0.0033)*** | **0.5396** |
| *Sub-national regions* | 1.3161 *(0.0510)* | | 0.0038 *(0.0087)* | 0.5768 |
| Ghana Western | | -0.0846 *(0.0790)* | 0.0201 *(0.0133)* | |
| Ghana Central | | 0.1821† *(0.0788)* | -0.0091 *(0.0133)* | |
| Greater Accra | | 0.1452 *(0.0894)* | -0.0166 *(0.0152)* | |
| Volta | | -0.1398‡ *(0.0736)* | -0.0072 *(0.0126)* | |
| Ghana Eastern | | -0.0926 *(0.0779)* | -0.0070 *(0.0131)* | |
| Ashanti | | — | — | |
| Brong-Ahafo | | -0.0494 *(0.0782)* | 0.0066 *(0.0137)* | |
| Ghana Northern | | -0.3218* *(0.0862)* | -0.0083 *(0.0146)* | |
| Ghana Upper West | | -0.4318* *(0.1226)* | 0.0112 *(0.0207)* | |
| Ghana Upper East | | -0.1001 *(0.1027)* | -0.0179 *(0.0176)* | |

** $p < 0.01$ for all coefficients of $\lambda_p$. * $p \leq 0.01$; † $p \leq 0.05$; ‡ $p \leq 0.1$. Standard Errors are in parentheses; — denotes reference region.*

**Table 7.7** ***(cont'd)***

| **Country** / **Region** | $\beta_i$: $\lambda_p$* | $\lambda_{pi}$ | $\lambda_{pti}$ | $R^2$ |
|---|---|---|---|---|
| ***COASTAL WEST AFRICA (cont'd)*** | | | | |
| **Togo** | **1.1297** ***(0.0190)*** | | **0.0002‡** ***(0.0028)*** | **0.6533** |
| *Sub-national regions* | 1.0787 *(0.0576)* | | -0.0047 *(0.0084)* | 0.6684 |
| Maritime | | 0.1755* *(0.0667)* | -0.0003 *(0.0098)* | |
| des Plateaux | | 0.1203‡ *(0.0708)* | 0.0018 *(0.0103)* | |
| Togo Centrale | | — | — | |
| de la Kara | | -0.1458† *(0.0738)* | 0.0197 *(0.0109)* | |
| des Savanes | | -0.0928 *(0.0742)* | 0.0100 *(0.0109)* | |
| **Benin** | **1.0128** ***(0.0304)*** | | **0.0169*** ***(0.0053)*** | **0.6597** |
| *Sub-national regions* | 1.1987 *(0.0770)* | | 0.0114 *(0.0130)* | 0.6851 |
| Atacora | | -0.0601 *(0.1030)* | -0.0131 *(0.0176)* | |
| Atlantique | | -0.0965 *(0.1130)* | -0.0051 *(0.0194)* | |
| Borgou | | — | — | |
| Mono | | -0.4369* *(0.1076)* | 0.0396† *(0.0186)* | |
| Oueme | | -0.1137 *(0.1177)* | -0.0003 *(0.0203)* | |
| Zou | | -0.4019* *(0.1025)* | 0.0103 *(0.0177)* | |
| **Nigeria** | **1.1343** ***(0.0153)*** | | **0.0030** ***(0.0025)*** | **0.6479** |
| *Sub-national regions* | 0.8909 *(0.0365)* | | 0.0120† *(0.0054)* | 0.7146 |
| Nigeria North East | | — | — | |
| Nigeria North West | | 0.0779 *(0.0482)* | -0.0178† *(0.0074)* | |
| Nigeria South East | | 0.4684* *(0.0522)* | -0.0166† *(0.0082)* | |
| Nigeria South West | | 0.2893* *(0.0500)* | 0.0101 *(0.0079)* | |
| Nigeria Central | | 0.3607* *(0.0507)* | -0.0064 *(0.0081)* | |

** $p < 0.01$ for all coefficients of $\lambda_p$. * $p \leq 0.01$; † $p \leq 0.05$; ‡ $p \leq 0.1$. Standard Errors are in parentheses; — denotes reference region.*

appeared distinctly different from the northern regions in 1985 with significantly higher values of $\beta$. This implies that higher age-specific death rates between the exact ages 1 and 5 years relative to infancy prevailed in northern Nigeria compared with moderate levels in the central and southern parts of the country.

Northwards in the continental zone of Sahel West African countries, Niger — which shares much of its southern border with Nigeria — has a national $\beta$ of less than 1. No country has a national $\beta$ of above 1.2. Thus, childhood mortality patterns varied between Princeton "North" and "South" in this part of the continent in 1985 except in Niger whose depicted pattern is more extreme than Princeton "North" (see Table 7.8). A significant rise in $\beta$ has occurred in Senegal and Niger but in Burkina Faso it has fallen.

**Table 7.8:** ***Regression coefficients determining the nature of and explaining national and sub-national variations in childhood mortality pattern in Sahel West Africa relative to Princeton "North" Level 15 for both sexes.***

| Country / Region | $\beta_i$: $\lambda_p^*$ | $\beta_i$: $\lambda_{pi}$ | $\beta_i$: $\lambda_{pti}$ | $R^2$ |
|---|---|---|---|---|
| ***SAHEL WEST AFRICA*** | | | | |
| **Senegal** | **1.0560** ***(0.0126)*** | | **0.0095*** ***(0.0022)*** | **0.6208** |
| *Sub-national regions* | 1.1856 *(0.0264)* | | 0.0097* *(0.0033)* | 0.6714 |
| Senegal West | | — | — | |
| Senegal Central | | -0.1873* *(0.0319)* | 0.0002 *(0.0040)* | |
| Senegal North East | | -0.0424 *(0.0402)* | 0.0001 *(0.0049)* | |
| Senegal South | | 0.0916† *(0.0393)* | -0.0019 *(0.0049)* | |
| **Mali** | **1.1376** ***(0.0119)*** | | **0.0033** ***(0.0021)*** | **0.7025** |
| *Sub-national regions* | 1.1629 *(0.0217)* | | 0.0098* *(0.0038)* | 0.7358 |
| Kayes/Koulikoro | | — | — | |
| Sikasso/Segou | | 0.1007* *(0.0301)* | -0.0141* *(0.0052)* | |
| Mopti/Gao/Timbouctou | | -0.2098* *(0.0312)* | -0.0082 *(0.0054)* | |
| Bamako | | 0.0457 *(0.0556)* | 0.0075 *(0.0096)* | |
| **Burkina Faso** | **1.1950** ***(0.0182)*** | | **-0.0106*** ***(0.0028)*** | **0.7186** |
| *Sub-national regions* | 1.1892 *(0.0334)* | | -0.0137* *(0.0050)* | 0.7315 |
| Ouagadougou | | -0.0364 *(0.0842)* | 0.0083 *(0.0141)* | |
| Burkina North | | -0.0242 *(0.0545)* | 0.0004 *(0.0084)* | |
| Burkina East | | 0.0516 *(0.0498)* | -0.0023 *(0.0074)* | |
| Burkina West | | -0.0136 *(0.0511)* | 0.0140 *(0.0078)* | |
| Burkina Central/South | | — | — | |
| **Niger** | **0.8637** ***(0.0127)*** | | **0.0066*** ***(0.0021)*** | **0.6105** |
| *Sub-national regions* | 0.8381 *(0.0258)* | | 0.0029 *(0.0042)* | 0.6589 |
| Niamey | | -0.0170 *(0.0829)* | 0.0202 *(0.0135)* | |
| Dosso | | 0.0550 *(0.0439)* | -0.0028 *(0.0073)* | |
| Maradi | | 0.0227 *(0.0362)* | 0.0124† *(0.0060)* | |
| Tahoua/Agadez | | -0.0190 *(0.0376)* | 0.0012 *(0.0063)* | |
| Tillaberi | | 0.0908† *(0.0423)* | -0.0014 *(0.0069)* | |
| Zinda/Diffa | | — | — | |

** $p < 0.01$ for all coefficients of $\lambda_p$. * $p \leq 0.01$; † $p \leq 0.05$; ‡ $p \leq 0.1$. Standard Errors are in parentheses; — denotes reference region.*

Significant regional differences in $\beta$ in 1985 were evident only in Senegal and Mali. Senegal Central and South Regions respectively manifested significantly low and high values of $\beta$ relative to that of the West Region; and Mopti/Gao/Timbouctou and Sikasso/Segou displayed a similar case in Mali relative to the region of Kayes/Koulikoro. Only Sikasso/Segou in Mali and Maradi in Niger have significantly different rates of change in $\beta$ over time from the rest of their respective countries.

### *7.3.2 Regional variations in $\beta$-value classification over time and validity of extrapolations*

Regional variations in the values of $\beta$ are best visualised cartographically. As demonstrated in Chapter 5 (Section 5.3.4), this approach facilitates comparison of the experiences of adjacent regions — especially those in different countries — as a way confirming or validating the results obtained. The results are mapped by computing aggregate values of $\beta$ for each region for the model reference date of 1985, as well as values relating to a decade earlier and to a decade later. This also demonstrates the extent to which predictions with respect to time can reasonably be made from the individual country models fitted. The computed values of $\beta$ for the respective three reference dates — i.e. 1975, 1985 and 1995 — are grouped according to the classification defined and presented in Table 7.3 that relates derived $\beta$-values to the Princeton families of model mortality patterns in childhood.

The distributions of the “underlying” patterns of childhood mortality in 1975 in Sub-Saharan Africa are shown in Figure 7.2. The map is generally chequered in nature with only Liberia and Cameroon manifesting a homogeneous pattern of childhood mortality in all their respective sub-national regions. The majority of sub-national regions had mortality patterns in childhood in 1975 within the range of the Princeton system, contrary to what the results in Chapter 5 suggested. The pattern deemed to be more extreme than the Princeton “North” models was restricted to Niger and Chad, eastern Ethiopia, the north-eastern part of the Southern African countries, and few other spots in West Africa. The Princeton “East” or more extreme than "East" pattern was the most prevalent. It was found in all continental sub-regions and involved two or more countries in each case. It occurs in Liberia, Côte d’Ivoire, and parts of Burkina Faso in West Africa; in Cameroon, southern Chad and much of Central African Republic in Middle Africa; southern and eastern parts of East Africa and north-western Ethiopia; and the greater part of southern and western areas of Southern African (see Figure 7.2). Cross-border similarities occur extensively in this period, perhaps the most significant — as was the case in Chapter 5 — being that involving Liberia and Côte d'Ivoire

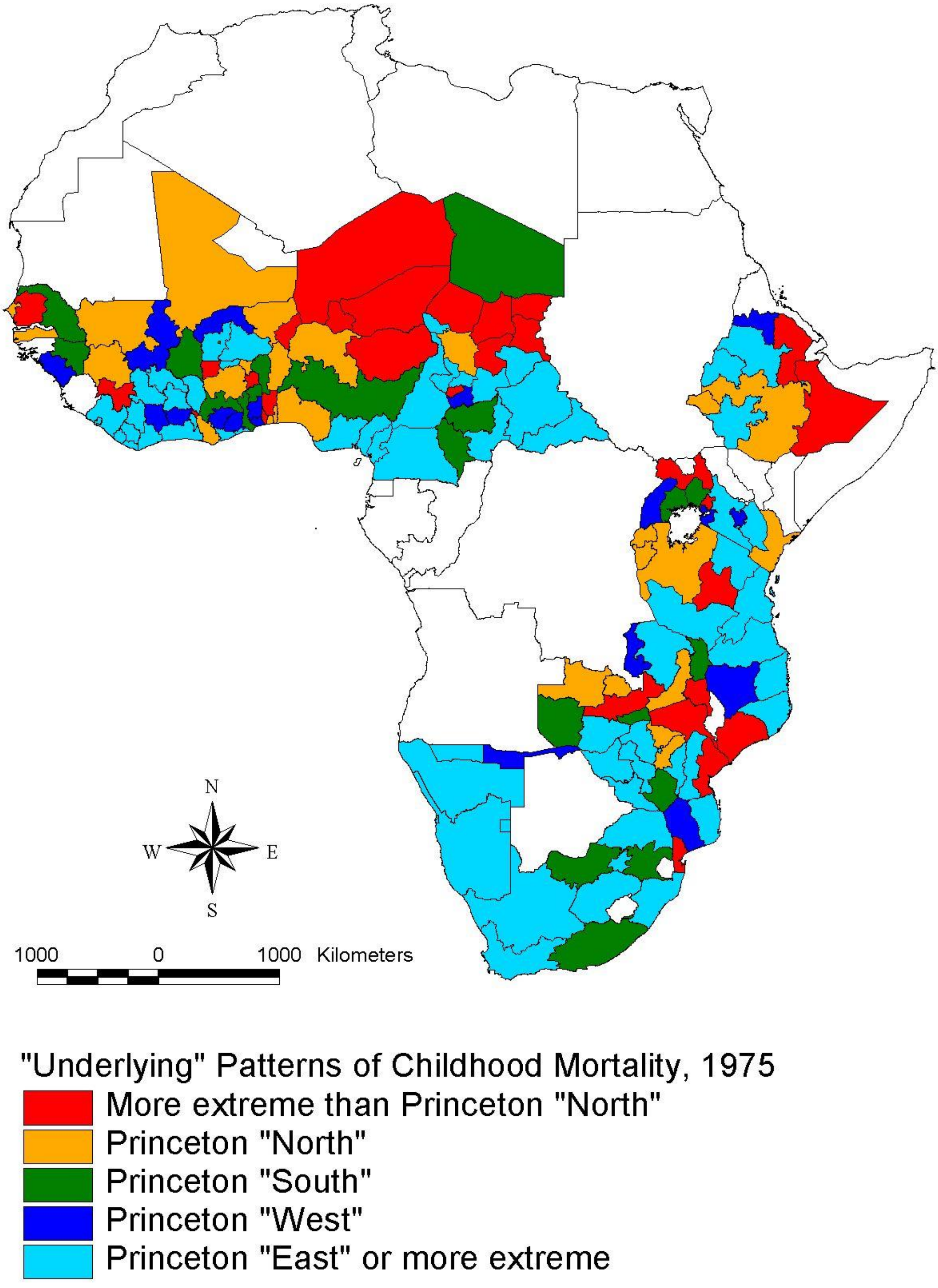



**Figure 7.2:** ***Distributions of the "underlying" mortality patterns in childhood based on the defined classification of derived $\beta$-values for the year 1975.***

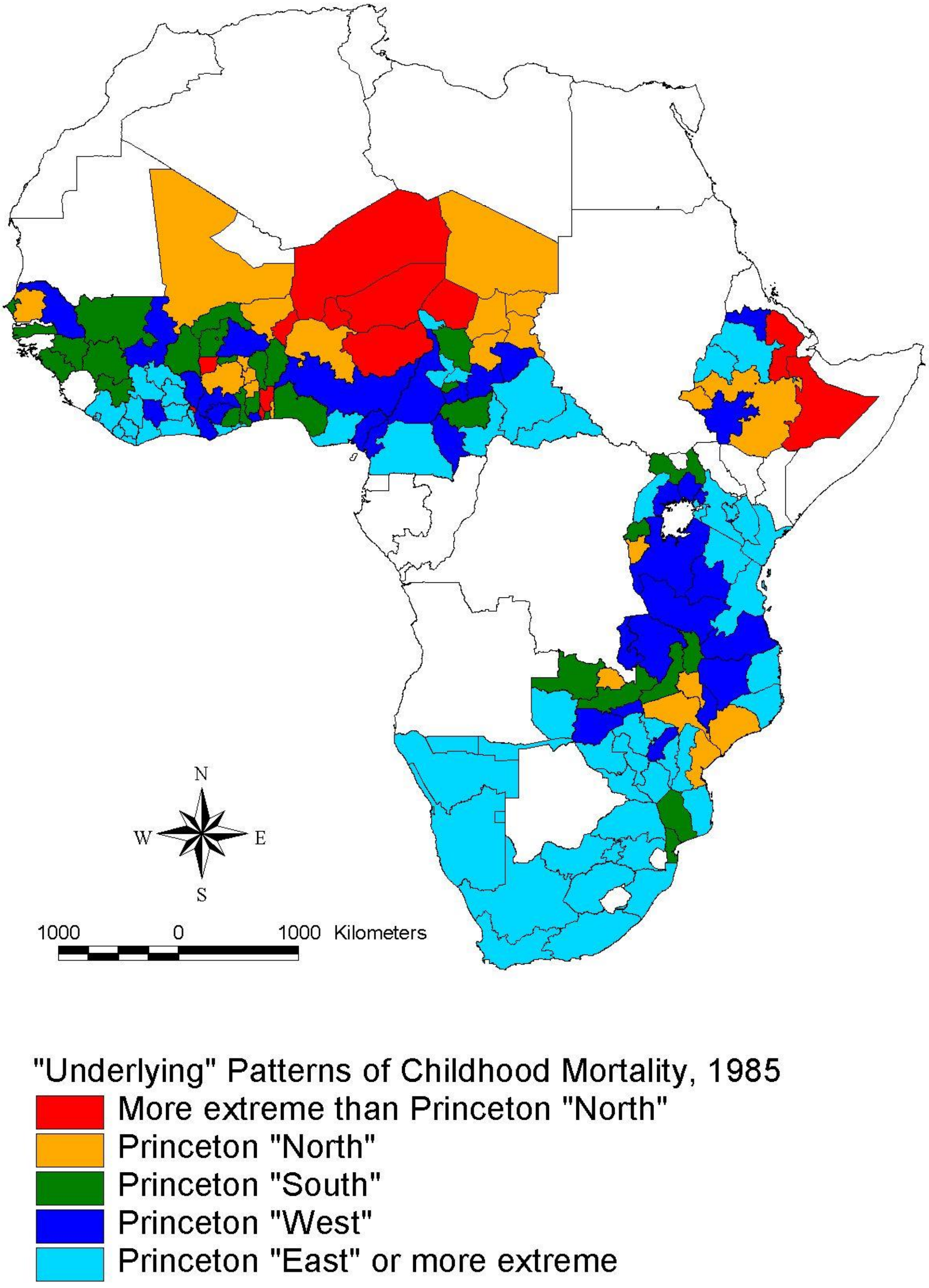



**Figure 7.3:** ***Distributions of the "underlying" mortality patterns in childhood based on the defined classification of derived $\beta$-values for the year 1985.***

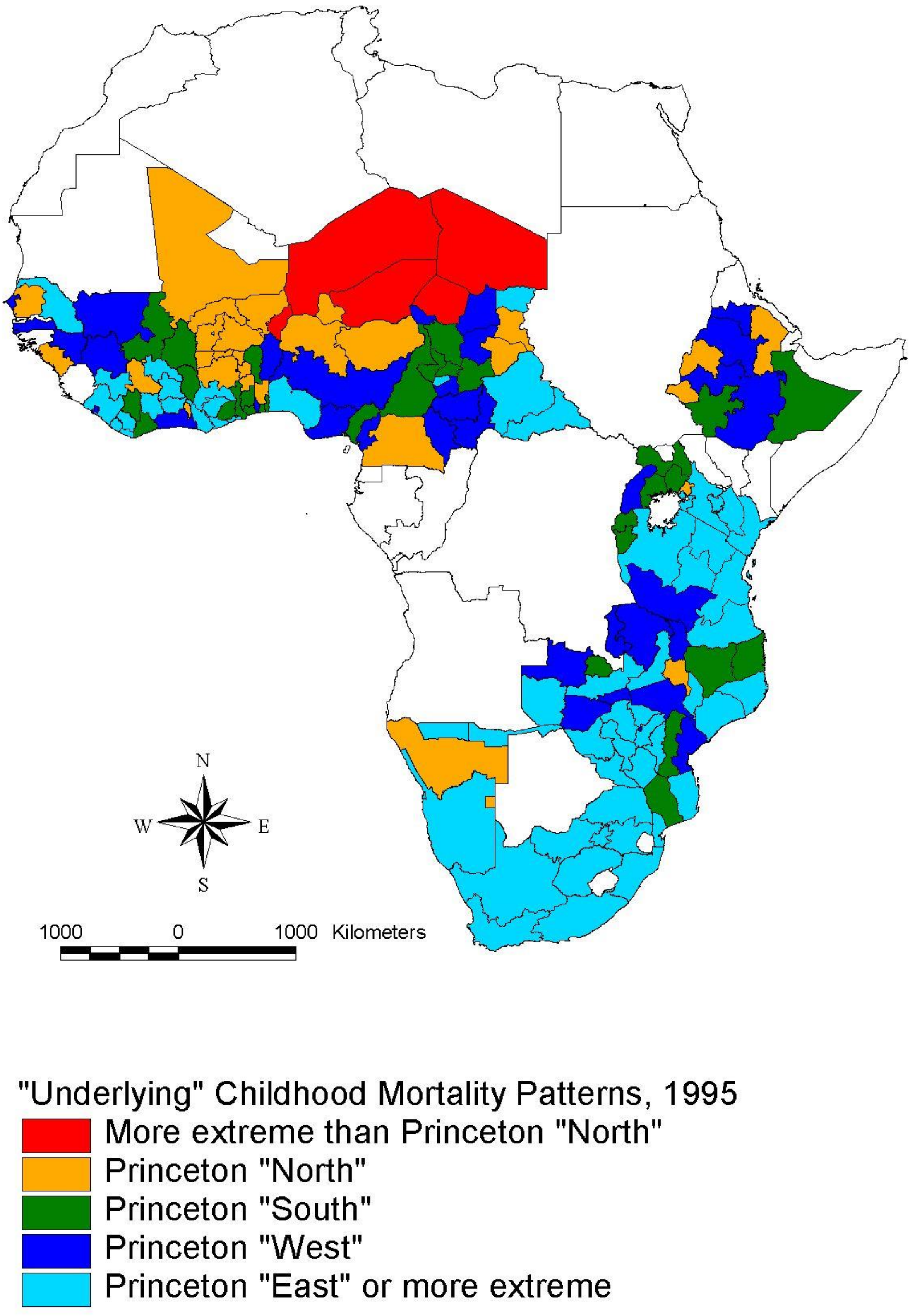



**Figure 7.4:** ***Distributions of the "underlying" mortality patterns in childhood based on the defined classification of derived $\beta$-values for the year 1995.***

confirming that the Princeton "East" pattern is the "underlying" pattern of childhood mortality in this part of West Africa.

A decade later in 1985, i.e. the model reference date, the underlying mortality pattern more extreme than "North" is confined to West Africa, especially Chad (see Figure 7.3). The Princeton “East” or more extreme than "East" pattern dominates in Southern Africa, Kenya and eastern Tanzania. The countries with high childhood mortality in these parts of the continent manifested other Princeton-type patterns of childhood mortality especially "West" in western Tanzania, northern Zambia, and northern Mozambique. In West Africa, the geographical areas that experience the Princeton “East” or more extreme than "East" pattern of mortality have shrunk southwards. Notwithstanding this, the whole of Liberia and parts of neighbouring Côte d’Ivoire continue to display that type of pattern. The “West”, “South” and “North” patterns appear further north, although the "West" pattern appears to be more prevalent overall. Interestingly, every pattern appears to have prevailed in at least one Ghanaian sub-national region.

By 1995 the mortality pattern more extreme than "North" disappeared in Ethiopia and Coastal West Africa, thus becoming confined to Niger and the northern parts of Chad. The Princeton “North” pattern extended southwards in West Africa, whilst the Princeton “East” and "West" became dominant in the southern parts of the same region. Eastern and Southern Africa continued to display the patterns that depict low child mortality relative to infant mortality, i.e. Princeton “West”, “East” or more extreme than "East", albeit with the emergence of a “North” pattern in Namibia.

The depicted “underlying” patterns of childhood mortality at the three dates in many cases cover huge geographical expanses that fall in at least two countries, thus implying significant cross-country similarities in "underlying" childhood mortality patterns. Considering that the national surveys were conducted independently at different dates, this patterning in the derived $\beta$-values for sub-national regions strongly suggests that the analysis is revealing real characteristics of African mortality schedules.

### *7.3.3 Geographical Distribution of $\gamma$-Values*

The analysis thus far has demonstrated that the parameter $\gamma$ constitutes an integral part in the determination of the prevailing mortality patterns in childhood in Sub-Saharan Africa. Its value in the respective national and sub-national models can be evaluated for any period of time from the results presented in Appendix 7. This discussion focuses on variation in the size of the mortality humps $\gamma$ represents over time and across the continent. The derived sub-national $\gamma$-values for the years 1975, 1985 and 1995 are presented in Figures 7.5 – 7.7. The classification used comprises six groups. The derived sub-national $\gamma$-values over the two decades covering 1975-1995 range from –1.6376 to 5.8348. However, about 90% of them fall between 0 and 1.5, especially in 1985 and 1995. Fewer than 10% of sub-national regions displayed $\gamma$-values of more than 1.5 in 1975; and only about 2% did in 1985 and 1995.

Perhaps the most surprising feature of the 1975 geographical distribution of $\gamma$-values as presented in Figure 7.5 is the clustering of high values in the southern part of the continent compared with the concentration of values of less than 0.6 in Western and Middle Africa and northern parts of Eastern Africa. Notwithstanding, large areas comprising sub-national regions of different countries display $\gamma$-values of less than 0.4 in Southern Africa. These include the north and central regions of Malawi and the neighbouring Mozambican regions of Niassa and Tête. Similarly, the north-eastern parts of South Africa display low levels of $\gamma$ together with neighbouring region of Gaza in Mozambique. A third area displaying $\gamma$-values of between 0.2 and 0.4 is made up of the southern regions of Zambia, neighbouring Mashonaland West and East and Matabeleland North in Zimbabwe, and Namibia North-east and Central.

With the exception of the northern and eastern parts of Niger, northern and south-eastern Nigeria and few other pockets displaying relatively high values of $\gamma$, Western and Middle Africa were characterised by $\gamma$-values of less than 0.6. The same also holds for the northern part of Eastern Africa except for the regions of Eastern Uganda and Tigray in Ethiopia. However, cross-country similarities were more prevalent in Western and Middle Africa (see Figure 7.5). It appears that high $\gamma$-values of 0.6 or more are associated with low levels of overall childhood mortality, and vice versa. This implies, therefore, that the excess mortality between the ages 6 and 23 months is more pronounced in situations of low overall childhood mortality.

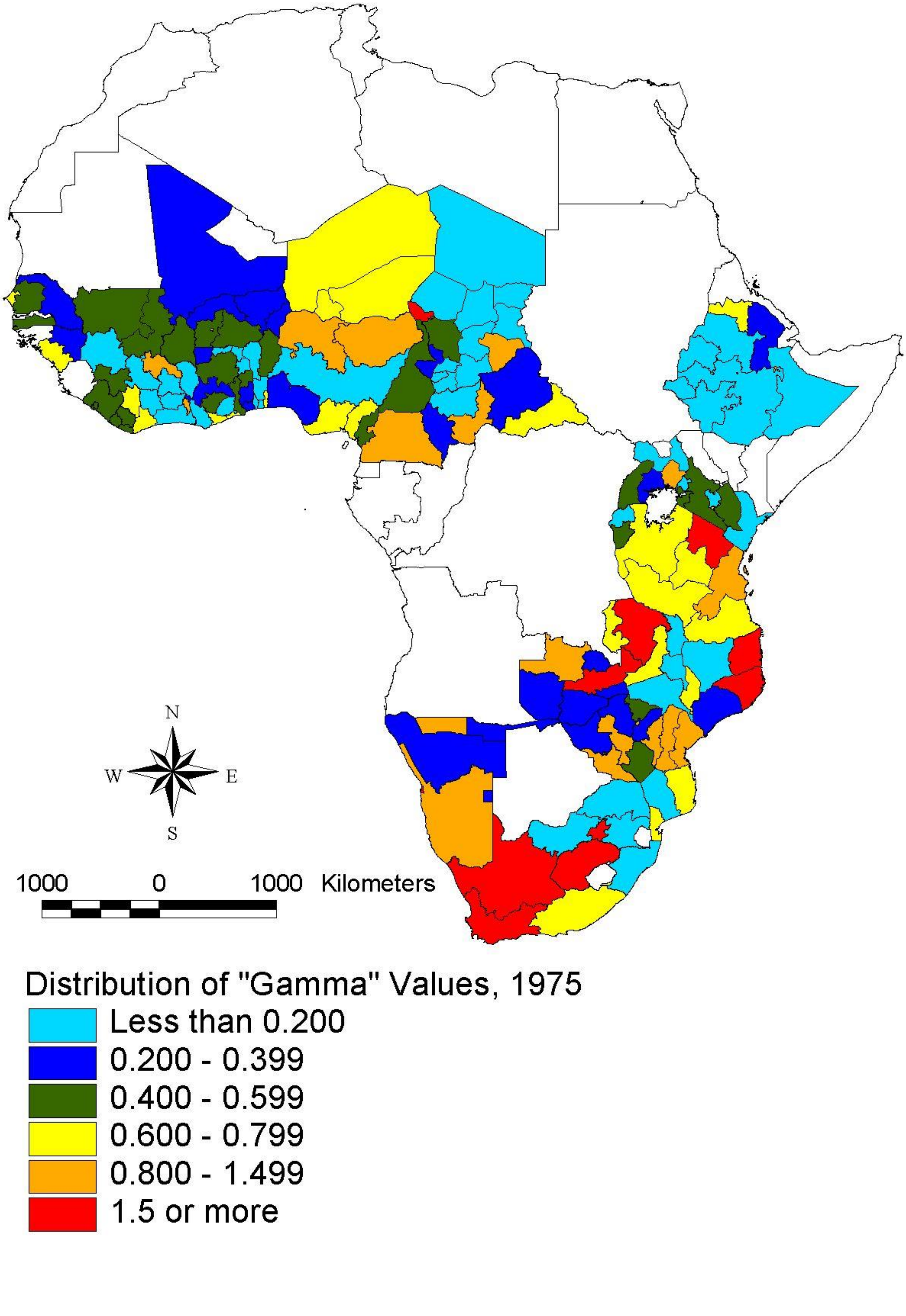



**Figure 7.5:** ***Geographical distribution of $\gamma$-values in 1975 based on fitted models.***

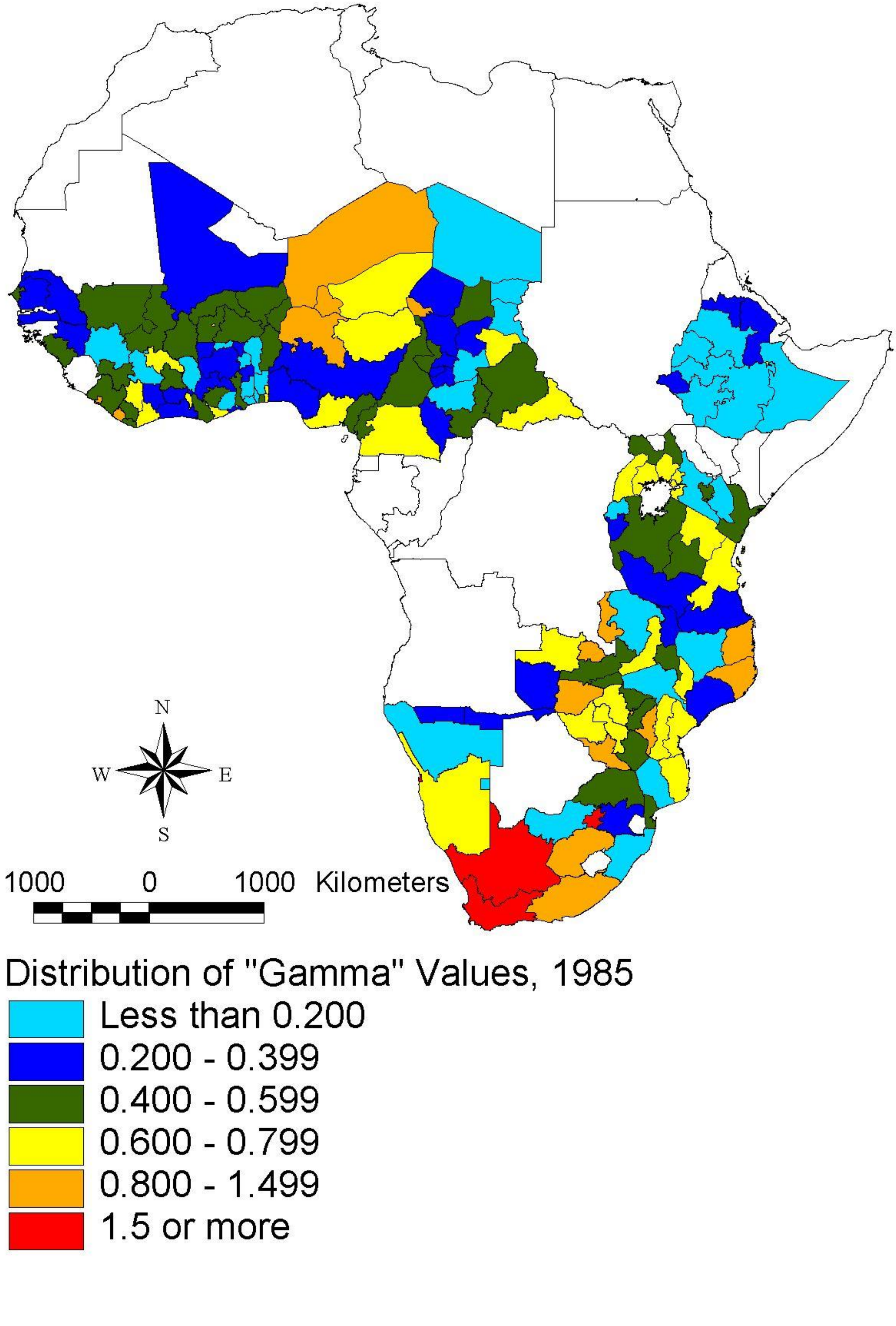



**Figure 7.6:** ***Geographical distribution of $\gamma$-values in 1985 based on fitted models.***

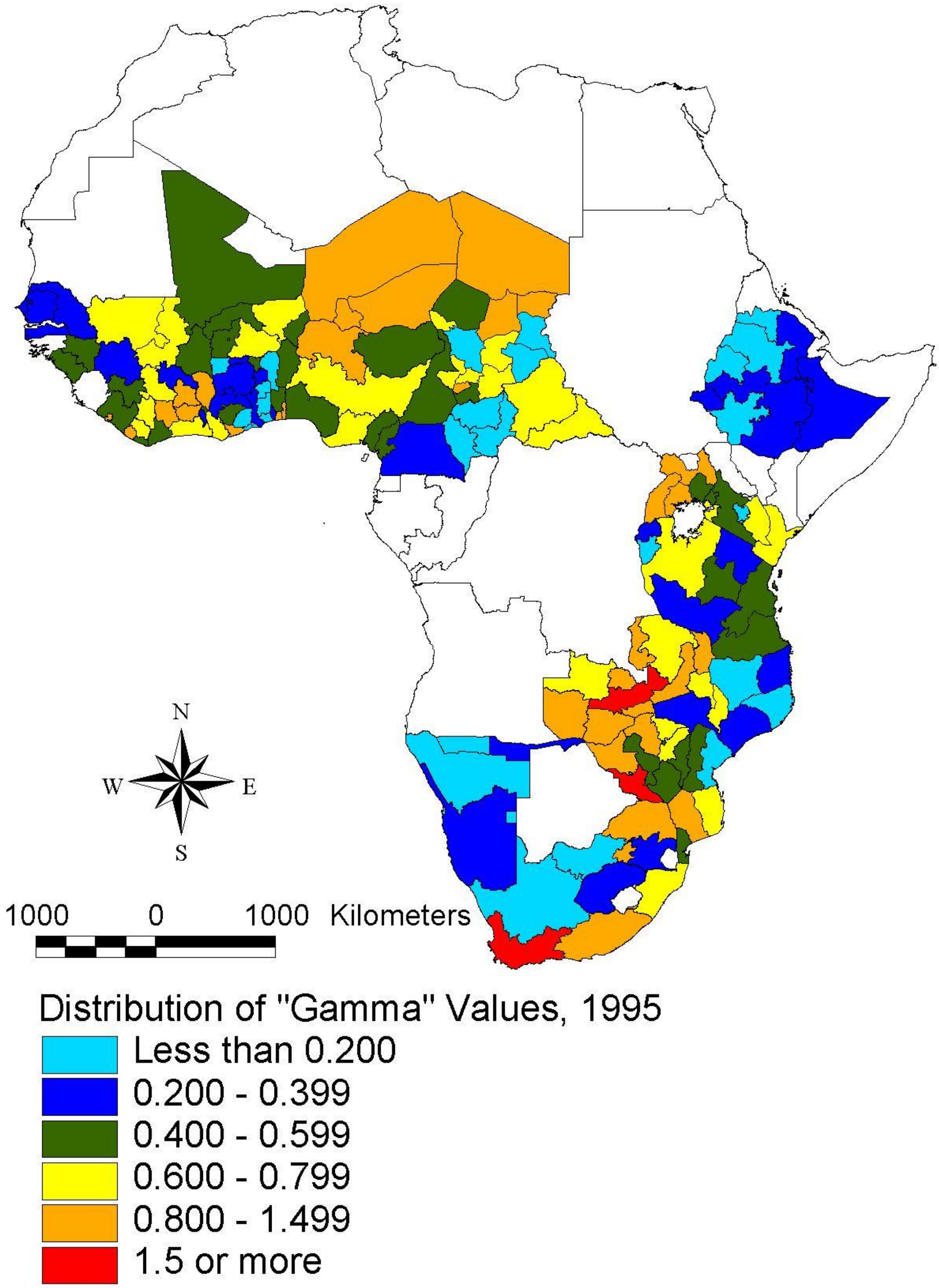



**Figure 7.7:** ***Geographical distribution of $\gamma$-values in 1995 based on fitted models.***

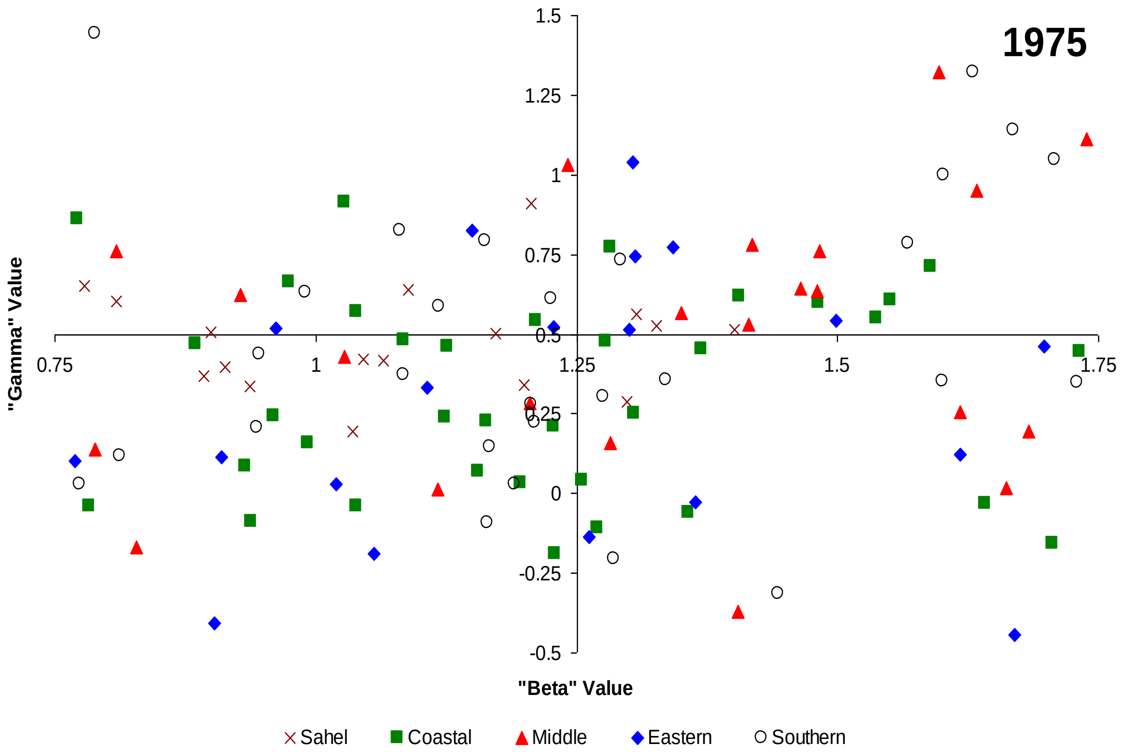
Figure 7.6 shows that most of the changes that occurred to the geographical distribution of $\gamma$-values in 1985 were concentrated in Eastern and Southern Africa. Whilst the upper extreme values of $\gamma$ became confined to the southern tip of the continent, the $\gamma$-values in much of Tanzania and central and northern Zambia fell to below 0.6. Generally, the distribution had become very chequered to the extent that cross-country similarities are less apparent. In West Africa, the situation in 1985 remains similar to the distribution that prevailed a decade earlier. In fact, using 0.6 as threshold, very minimal changes can be said to have occurred in West and Middle Africa, or in Kenya and Ethiopia in Eastern Africa. The observation of a degree of association between overall childhood mortality level and $\gamma$-value deduced earlier from the documented distribution of childhood mortality levels in the continent was also evident in 1985.

The next decade saw $\gamma$-values in middle and eastern parts of Western Africa rise to values of 0.6 or more, but no region manifested a value of 1.5 or more (see Figure 7.7). South-western Kenya and much of Uganda also experienced increases in $\gamma$ in 1995 relative to 1985 figures. A possible explanation of this observation in West Africa is the decline in overall childhood mortality recorded in much of this part of the continent if the earlier observations from the 1975 and 1985 $\gamma$ distributions are anything to go by. Despite the changes, widespread cross-border similarities in $\gamma$-values remain.

Southern Africa witnessed the re-emergence of the upper extreme $\gamma$-values in Zambia Central and Matabeleland South in Zimbabwe by 1995. Also, more sub-national regions in this area displayed values of between 0.8 and 1.5 than was the case a decade earlier in 1985. In contrast, the south-western part of this sub-continental region covering the whole of Namibia and the central and north-western regions of South Africa, as well as northern Mozambique, became characterised by $\gamma$-values of less than 0.4 in 1995.

### *7.3.4 Association between $\beta$ and $\gamma$*

This section assesses the association between $\beta$ and $\gamma$-values on the basis of their respective distributions for the periods 1975, 1985 and 1995. Scatter diagrams are used to determine whether there exist clusters of sub-national regions from the same part of the continent that



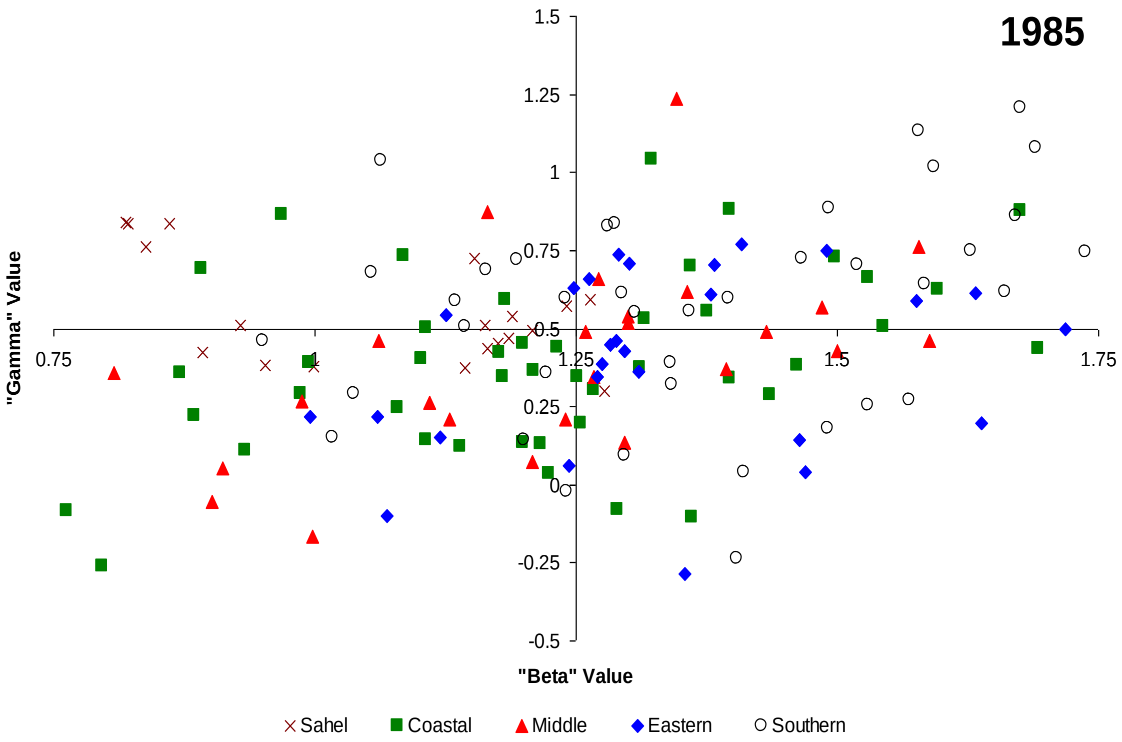
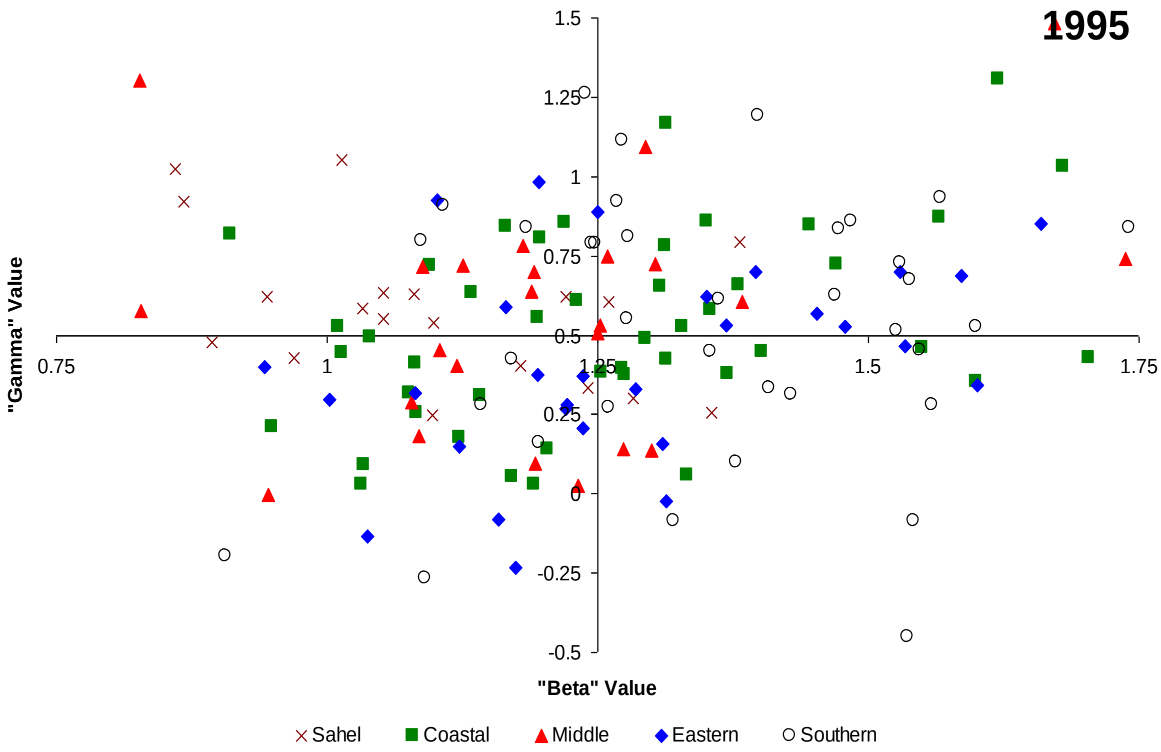




**Figure 7.8:** ***Scatter diagrams of β against corresponding value of γ by continental sub-region and period.***

**Figure 7.8** — *continued.*




have similar $\beta$ and $\gamma$-values, thus constituting African "regional" patterns of childhood mortality. Figure 7.8 shows the distribution of the two parameters by continental sub-region. As the three graphs reveal, no systematic pattern can be readily identified for any continental sub-region from the distributions depicted. Every part of the continent has sub-national regions displaying $\beta$ and $\gamma$-values spanning the parts of the axes shown in the graphs. However, the majority of $\beta$-values for regions in the Sahel fall between 0.75 and 1.25 (i.e. on the left hand side of the graphs), whilst most of those for regions in Southern Africa fall between 1.25 and 1.75 (i.e. on the right hand side of the graphs). But the large variations in the corresponding $\gamma$-values for both continental sub-regions make it difficult for meaningful clusters of points to appear. Thus no potential set of geographically contiguous sub-national regions exist that can be used to construct an average "regional" pattern of mortality in childhood.

## 7.4 Summary

This chapter set out to assess the significance of the evidence in support, or otherwise, of the patterns of childhood mortality identified in Chapter 5. More specifically, it attempted to confirm or dismiss the notion that the "humps" identified in the mortality schedules of most sub-national regions of the 26 countries considered are in fact responsible for the rather unusual childhood mortality patterns identified. On this basis, an assessment was made as to what progress can be made towards the advancement of methods for childhood mortality estimation in Sub-Saharan Africa.

Controlling for the "humps" of excess mortality identified in Chapter 6 in the fitted country models has yielded $\beta$-values that conform to Princeton patterns of mortality. This helps to resolve what has been a puzzle surrounding childhood mortality patterns in Sub-Saharan Africa for years. The situation portrayed by Figure 5.11 regarding the distribution of prevalent childhood mortality patterns based on infant-to-child mortality relationships results when national and sub-national models are fitted without allowing for the "humps", i.e. using the conventional two-parameter model. This is represented in Figure 7.1 by the broken line, which is essentially a regression line of best fit that attempts to include the outlying points representing the ages affected by the hump. The gradient of the line is inevitably compromised, yielding lower values of $\beta$, that produce higher age-specific death rates in the older ages of childhood relative to the age brackets within infancy; and consequently higher ${}_4q_1$ relative to ${}_1q_0$. On the basis of the modelling results, therefore, Figure 5.11 does not adequately represent childhood mortality patterns in the continent.

As far as the individual country models are concerned, they have established the fact that mortality patterns vary both within and between countries, as well as over time with differing rates of change at the sub-national level. The same also applies to the level of mortality relative to the Princeton "North" level 15 for both sexes, and the intensity of the excess mortality "hump" between the ages 6 and 23 months. What is believed to be close to the true prevailing childhood patterns of mortality in the continent are best demonstrated through life table representation since they are affected by the size of the "hump", $\gamma$, especially.

# Chapter 8

# Life Table Representation of Childhood Mortality and Prospects for Methodological Advances

## 8.1 Introduction

The fitted country models in the previous chapter set out to represent both national and sub-national mortality schedules in relation to that of a known and well established model life table. These national models have demonstrated that the observed mortality schedules in childhood can be modelled as a combination of three segments covering different ages in childhood, viz.: 0-5 months, 6-23 months, and 24-59 months. The only difference between the three is the prevalence of excess mortality, represented by $\gamma$, in the middle segment. The pattern of mortality, $\beta$, and level relative to the standard, $\alpha$, remain the same for all three segments. The fitted pattern of mortality that the combination of the three age spans depicts can be determined by constructing a life table using the coefficients obtained since the age-specific death rates for the standard mortality model, ${}_{n}m^{s}_{x}$, are known.

Using this approach and the results of the previous chapter, this chapter attempts to derive, apply and evaluate national life tables covering childhood and adolescence, specifically aiming to answer the following questions:

iii. What are the prospects for the construction of a life table system for Sub-Saharan Africa on the basis of the information at hand, that adequately reflects the main features of mortality in the first two years of life found in the various sub-national populations of the continent?

iv. Can any provisional national or continental standard life table generated in the process enhance future research on mortality in the continent — especially in childhood?

## 8.2 Life Table Representation of True Pattern of Childhood Mortality

The representation of the true pattern of childhood mortality in the form of a life table is illustrated in the construction of a period relational life table — a national one for the Sahel West African country of Burkina Faso. For convenience, the life table will relate to the year 1985, the model reference date. The parameters required, therefore, are the base ones in each case, i.e. $\lambda_0$ in the case of $\alpha$; $\lambda_h$ for $\gamma$; and $\lambda_p$ for $\beta$. From Appendices 6 and 7, the required values of $\alpha$ and $\gamma$ for Burkina Faso are 0.7865 and 0.5227 respectively, and the corresponding value of $\beta$ from Table 7.8 is 1.1950. The relational age specific death rates, ${}_nm_x$, are then computed from the relationships

$${}_nm_x = e^{\alpha} \cdot \left({}_nm_x^s\right)^{\beta} \qquad \text{for } 0 \le x < 6 \text{ and } 24 \le x < 60 \text{ months; and}$$

$${}_nm_x = e^{(\alpha+\gamma)} \cdot \left({}_nm_x^s\right)^{\beta} \qquad \text{for } 6 \le x < 24 \text{ months.}$$

The fitted life table is presented in Table 8.1. It is apparent that whilst the risks of dying in the neonatal and early post-neonatal periods were much higher in Burkina Faso in 1985 than those implied by the standard model mortality pattern, the age groups assumed to be affected by the "hump" of excess mortality register risks of death more than twice those in the standard life table. In fact, there is a slightly greater risk of dying in the age interval 6-8 months than in the 3-5 month age bracket. The low value of $\beta$ means that between ages 24 and 59 months, the risks of dying are rather similar. Assuming that the fitted parameters of $\alpha$ and $\beta$ also hold for the five-year age groups between exact ages 5 and 25 years, the values of ${}_nm_x$ of the life table being constructed can be extended to cover later childhood and adolescence.

The next step of the life table construction is the conversion of the age-specific death rates into probabilities of dying, ${}_nq_x$. The conventional actuarial formula for this is

$${}_nq_x = \frac{n \cdot {}_nm_x}{1 + \left(n - {}_na_x\right) \cdot {}_nm_x}$$

where $n$ is the interval between exact ages $x$ and $x+n$, and ${}_na_x$ is the average proportion of time

**Table 8.1:** ***Derived Relational Life Table from birth to age 20 years for Burkina Faso using country model parameters relating to 1985.***

| Age | "North" Level 15 Both Sexes | | Burkina Faso 1985 Relational Life Table | | | |
|---|---|---|---|---|---|---|
| *(in years)* | $l^s(x)$ | $m^s(x)$ | $m(x)$ | $q(x)$ | $p(x)$ | $l(x)$ |
| 0 | 1.0000 | 0.2780 | 0.4755 | 0.0389 | 0.9611 | 1.0000 |
| 0.083 | | 0.1571 | 0.2405 | 0.0393 | 0.9607 | 0.9611 |
| 0.25 | | 0.0900 | 0.1236 | 0.0304 | 0.9696 | 0.9234 |
| 0.50 | | 0.0590 | 0.1258 | 0.0310 | 0.9690 | 0.8953 |
| 0.75 | | 0.0439 | 0.0885 | 0.0219 | 0.9781 | 0.8676 |
| 1 | 0.9070 | 0.0350 | 0.0675 | 0.0167 | 0.9833 | 0.8486 |
| 1.25 | | 0.0253 | 0.0458 | 0.0337 | 0.9663 | 0.8344 |
| 2 | 0.8833 | 0.0168 | 0.0166 | 0.0165 | 0.9835 | 0.8062 |
| 3 | 0.8686 | 0.0128 | 0.0120 | 0.0120 | 0.9880 | 0.7930 |
| 4 | 0.8575 | 0.0099 | 0.0089 | 0.0089 | 0.9911 | 0.7835 |
| 5 | 0.8490 | 0.0057 | 0.0046 | 0.0225 | 0.9775 | 0.7765 |
| 10 | 0.8253 | 0.0032 | 0.0023 | 0.0113 | 0.9887 | 0.7590 |
| 15 | 0.8122 | 0.0039 | 0.0029 | 0.0142 | 0.9858 | 0.7504 |
| 20 | 0.7967 | 0.0051 | 0.0040 | 0.0200 | 0.9800 | 0.7397 |

***Sources:*** *Coale et al. (1983) and own calculations.*

(in years) lived between ages $x$ and $x+n$ by those who die in that age interval. Chiang (1984) and Preston *et al*. (2001) give different techniques of estimating ${}_na_x$, as well as recommended general sets of figures for different populations. In all instances, they relate to age intervals of at least one year, and there does not seem to exist in the demographic literature any set of ${}_na_x$ values recommended for use in childhood ages with intervals as short as one month. While the birth histories contained in the DHS datasets used in the study have all the information required to calculate directly population-based estimates ${}_na_x$, doing so for all countries and for every sub-national region would be extremely cumbersome and time consuming. Moreover, directly observed ${}_na_x$ values are influenced by the population's age distribution within the time width of the age interval (Preston *et al*., 2001).

It is unlikely that any specific set of ${}_na_x$ values for the short age intervals concerned would be appropriate for all countries and sub-national regions. However, it has been assumed from the outset that the age-specific death rates remain constant in the respective age intervals $x$ to $x+n$. On this assumption the ${}_na_x$ values become redundant and a direct conversion can be made from the relationship

$$ {}_n q_x = 1 - e^{-n \cdot {}_n m_x} $$

The resulting probabilities of dying within each age interval and the corresponding survivorship estimates for Burkina Faso in 1985 are shown in Table 8.1. Using this procedure and the corresponding parameters of $\alpha$, $\gamma$ and $\beta$ for all 26 countries considered in this study, national period life tables have been constructed for the period 1975 to 1995 in five-year intervals. These are presented in Appendix 8. The same can be done for any sub-national region of interest for any period of time.

In countries and communities such as those in Sub-Saharan Africa, demographic data are scarce or of questionable quality. To the extent that these life tables provide a reliable description of their respective mortality situations, they constitute a useful tool for procedures ranging from demographic estimation to health policy formulation and intervention design. As an illustration of the value of the fitted national relational life tables, two are put to work. To start with, the life table for Burkina Faso in 1985 is used with information on proportions dead of children ever born by age of mothers contained in the Burkinabe DHS 2 dataset to estimate under-5 mortality. The same procedure is applied in Malawi using its 1990 relational life table, increasing the range of datasets to include censuses conducted in 1977 and 1987, as well as a national demographic survey held in 1982.

## 8.3 Application of Derived Relational Life Tables to Brass's 5q0 Indirect Estimation Technique: Examples of Burkina Faso and Malawi

*Burkina Faso*

As discussed in Chapter 4 (Section 4.4.4), the choice of mortality model to use in the indirect estimation of ${}_5q_0$ using variants of Brass's technique is usually not an easy decision to make. In fact, some instances may demand a trial of all four families of the Princeton system to determine which one yields the most consistent results. The more appropriate the model life table used, the more reliable and accurate the ${}_5q_0$ estimates obtained. In this regard, a comparison is made between estimates obtained using the 1985 Burkina Faso relational life table and those obtained using the Princeton "North" level 15 for both sexes to determine which one seems to better describe the Burkinabe pattern of mortality in childhood and early adulthood. The estimation procedure applied in Chapter 4 is adopted; and the correction factors and time location coefficients associated with the "North" family are used in both estimations. The results are displayed in Table 8.2. It is apparent that the relational life table yields higher levels of ${}_5q_0$ than the Princeton "North" life table for periods further back in the past. Although the reverse holds for the most recent periods, the most recent estimate is not considered since it generally overestimates the level of under-5 mortality at the reference date.

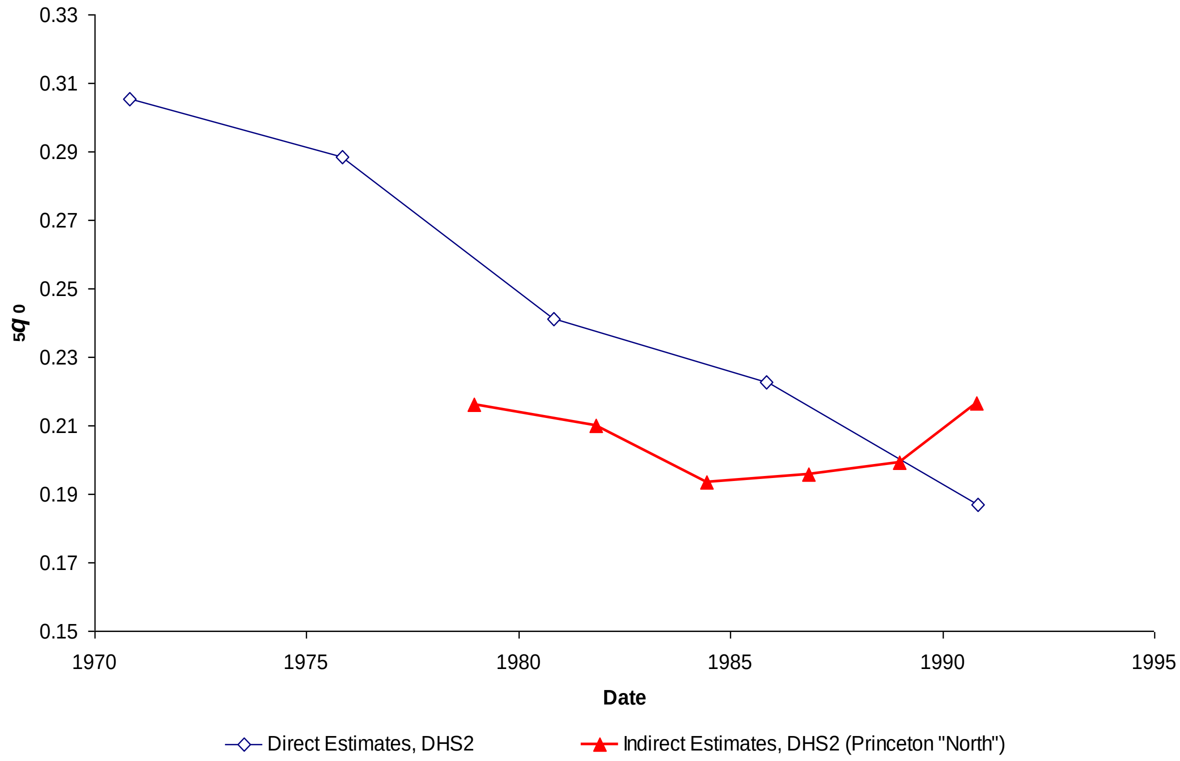
The appropriateness of the two life tables for the estimation of ${}_5q_0$ can be judged by comparing the derived estimates with those directly obtained from the same dataset. Since the data types (i.e. proportions dead of children ever born and dated birth histories) used in the two different techniques to generate the sets of ${}_5q_0$ estimates come from the same source, ideally they should depict the same levels and trend over at least fifteen years before the survey. The two sets of indirect estimates are graphed separately with the direct estimates in Figure 8.1. Using the Princeton "North" pattern to convert the $q(x)$ series to $q(5)$ significantly under-estimates ${}_5q_0$ for earlier dates relative to the direct estimates and produces an overestimate from the data on women aged 20-24. This was noted in Chapter 4 (Section 4.5), not only for Burkina Faso, but also for Mali and Niger in all their respective national DHS datasets (see Figure 4.5). The Burkina Faso 1985 relational life table yields a set of estimates of $q(5)$ that compare more closely with

**Table 8.2:** ***Sets of ${}_5q_0$ estimates obtained for Burkina Faso using its 1985 relational life table and the Princeton "North" model pattern.***

| | Proportions Dead of CEB | $q(x)$ | date | Using 1985 Burkina Faso Life Table | | Using Princeton "North" Life Table | |
|---|---|---|---|---|---|---|---|
| | | | | alpha | $q(5)$ | alpha | $q(5)$ |
| 15-19 | 0.1608 | 0.1650 | 1992.06 | 0.0510 | 0.2417 | 0.3280 | 0.2552 |
| 20-24 | 0.1719 | 0.1705 | 1990.80 | -0.0784 | 0.1975 | 0.2208 | 0.2166 |
| 25-29 | 0.1844 | 0.1749 | 1988.99 | -0.1043 | 0.1894 | 0.1686 | 0.1994 |
| 30-34 | 0.1986 | 0.1956 | 1986.84 | -0.0843 | 0.1956 | 0.1565 | 0.1956 |
| 35-39 | 0.2122 | 0.2222 | 1984.44 | -0.0526 | 0.2057 | 0.1498 | 0.1935 |
| 40-44 | 0.2486 | 0.2570 | 1981.82 | 0.0195 | 0.2303 | 0.2013 | 0.2101 |
| 45-49 | 0.2796 | 0.2836 | 1978.95 | 0.0590 | 0.2446 | 0.2195 | 0.2162 |

*P1/P2 = 0.1684; P2/P3 = 0.4792; Survey Date = 1993.13*

***Sources:*** *Burkina Faso DHS 2 (1992) and own calculations.*



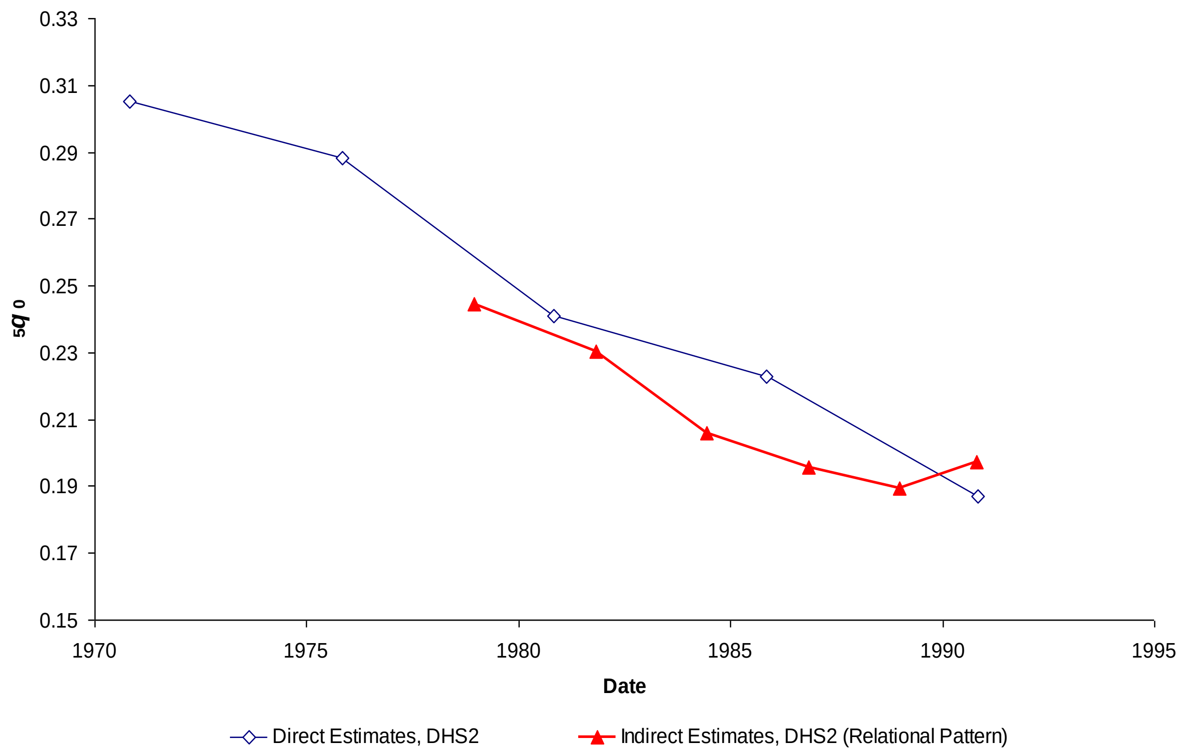




**Figure 8.1**: ***Comparison of indirect estimates of $_5q_0$ for Burkina Faso using different mortality patterns against the direct estimates obtained from the same dataset.***

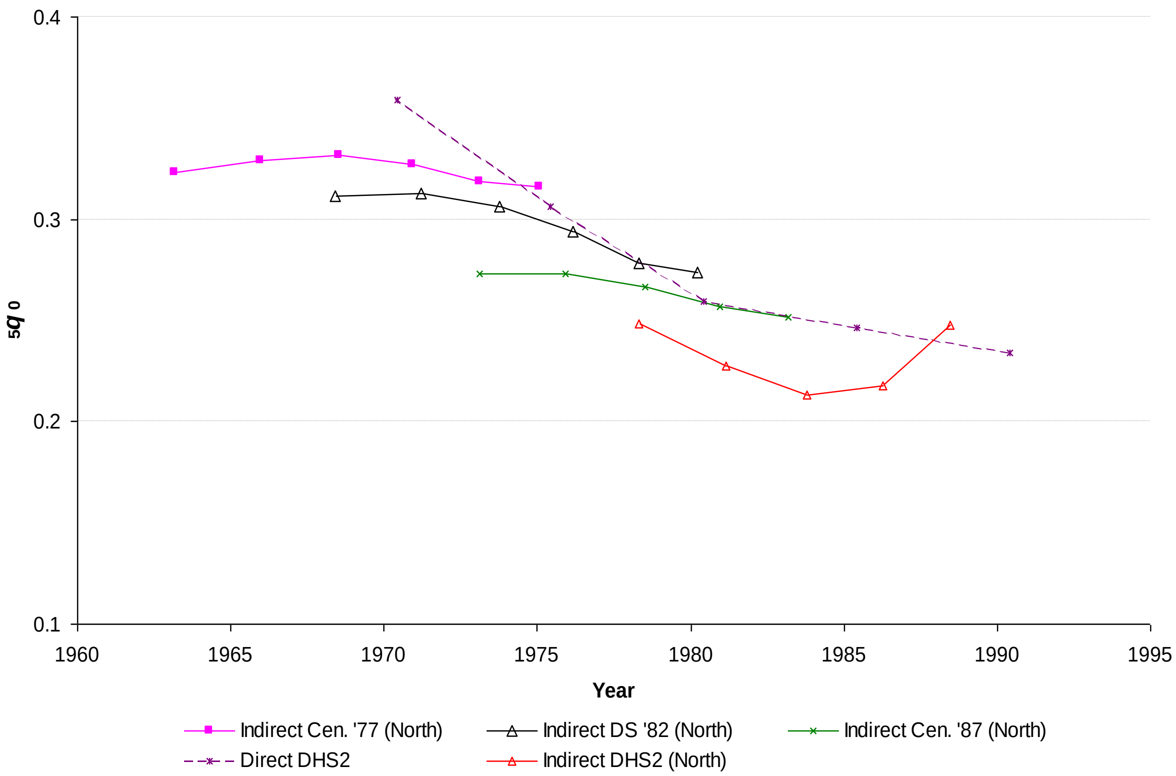
the directly derived estimates for the entire time span they cover. It is possible that the development of a new set of correction factors and time location coefficients based on the fitted model life tables would bring the indirect estimates even more closely in line with the direct estimates.

*Malawi*

One question that arises in the use of DHS data to improve indirect estimation of ${}_5q_0$ is whether it requires a fitted relational life table for a similar or only slightly earlier date. In other words, does the rate at which the pattern of mortality changes in a country or sub-national region have sufficient impact on a procedure such as indirect estimation to warrant concern? An attempt is made to assess this using data from Malawi. In addition to the national DHS 2 conducted in 1992, relevant data from the country's censuses of 1977 and 1987, and another demographic survey of 1982 are used to generate sets of ${}_5q_0$ estimates using the Princeton "North" models in the first instance, and then the fitted relational life table for Malawi in 1990 presented in Appendix 8. Both sets of results are presented graphically against the direct estimates obtained from the birth histories of the DHS in Figure 8.2.

The trends depicted by the estimates yielded by the Princeton "North" pattern are similar to those presented in Figure 4.5. They collectively produce a rather disjointed and vague indication of the trend of under-5 mortality in Malawi between 1964 and 1990. As observed in Burkina Faso, estimates for dates further back in the past are significantly lower than is indicated by the direct estimates. None of the sets of indirect estimates reflect the relatively rapid decline of ${}_5q_0$ indicated by the direct estimates in the decade of the 1970s. The estimates obtained with the 1990 Malawi life table reveal a more consistent trend of under-5 mortality irrespective of the source and date of the data used. The different sets of estimates link up with each other closely, and reflect the decline depicted by the direct estimates.

To assess the sensitivity of the results to the choice of life table, the same estimation procedure is repeated using derived Malawian life tables referring to about 3 years prior to the dates of the respective surveys. Choosing a pattern of mortality that prevailed about three years prior to the survey will ensure that the most recent estimates (including the first) are



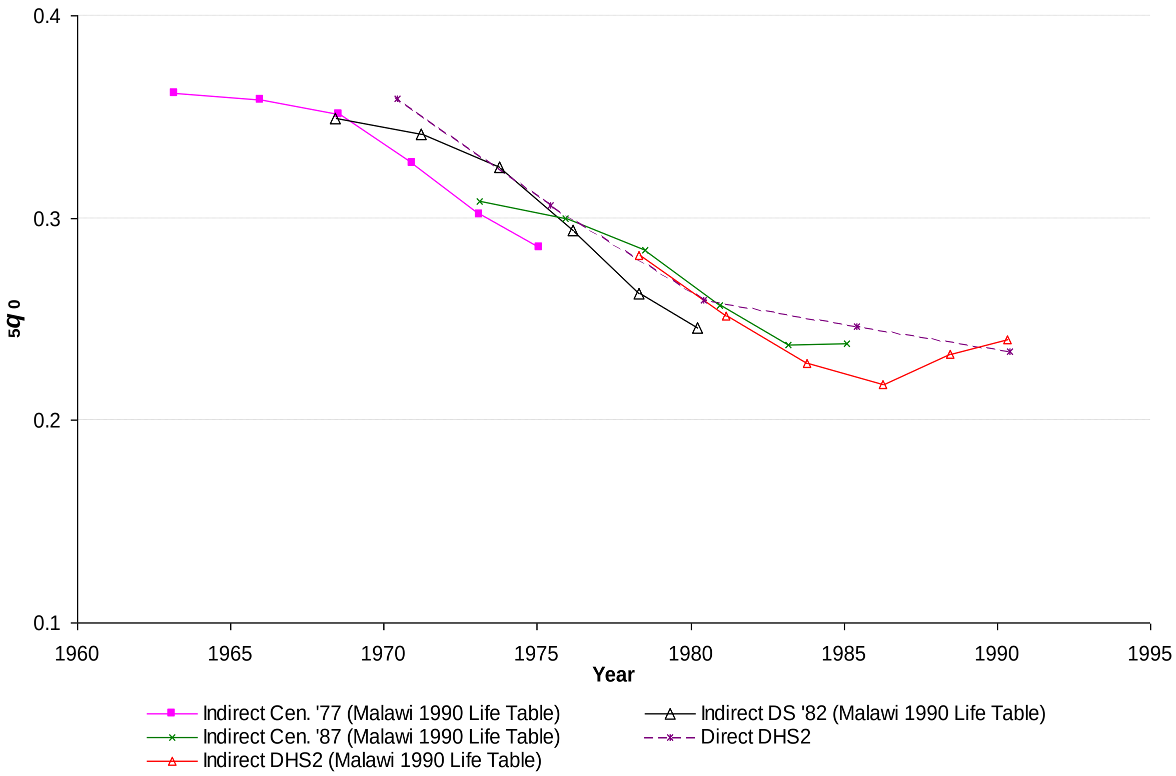




**Figure 8.2**: ***Comparison of indirect estimates of $_5q_0$ for Malawi obtained using the Princeton "North" pattern against those obtained using the derived 1990 Malawi relational life table.***

unbiased and seems appropriate. In this regard, under-5 mortality in Malawi is estimated from the 1977 Census dataset using the Malawi 1975 Life Table; from the 1982 Demographic Survey using the country's 1980 Life Table; from the 1987 Census using the 1985 Life Table; and from the 1992 DHS dataset using the 1990 Life Table. The results are presented graphically against the direct estimates from the DHS birth histories in Figure 8.3.

The results obtained collectively demarcate the most consistent indirect estimates of childhood mortality in Malawi between 1964 and 1990. The problem of over-estimation in the most distant estimates has been rectified as has the slight downward bias in the most recent estimates from the 1977 census and the 1982 Demographic Survey data. It appears, therefore, that the under-estimation has everything to do with the chosen life table. Mortality conditions within childhood in 1990 were much better than in the 1970s and 1980s in Malawi, and with a different pattern than prevailed in the recent past. Therefore, the 1990 Malawi life table did


**Figure 8.3:** ***Trends in $_5q_0$ in Malawi depicted by indirect estimates using different life tables derived for the country.***

not fully reflect the conditions that prevailed more than a decade earlier, hence the under-estimated values of ${}_5q_0$. As a result of using the different time-specific life tables, the independent sets of estimates almost perfectly match each other.

This example has demonstrated that the derived national life tables can be used with data from other sources for the estimation of childhood mortality. Variation in age patterns of mortality over time as well as between populations has an adverse impact on indirect estimates of under-5 mortality. The fitted country models may be of some value in improving the reliability of indirect estimates of childhood mortality in Sub-Saharan Africa.

## 8.4 Prospects for New African Models

The rationale for developing model life table systems is to represent the mortality experiences of populations from a wide range of geographical areas and different dates. Such a general representation is extremely useful in demographic estimation and modelling processes. It is on the basis of this premise that existing model systems were developed. With the exception of the Hypothetical West African Model (United Nations, 1982a), no such proposal has been made for Sub-Saharan Africa since Brass's "African Standard". Do the DHS birth histories and the current analysis hold out prospects for more representative new African life tables? The answer to this question depends on the extent of variation with respect to mortality characteristics between different populations across the continent, as well as the consistency of pattern of mortality over time.

The analysis presented above has revealed two main issues that will clearly impede the formulation of model life tables that would be representative of the experience of significant numbers of African populations. First, with the exception of the southwest of Africa, marked sub-national differences in $\beta$ and $\gamma$ prevail. This makes it difficult to delineate meaningful geographical areas with uniform childhood mortality patterns. This is apparent from the distributions of the respective parameters for the specified periods presented in Figures 7.2 - 7.7, as well as from the limited degree of association between the two parameters. The second problem is time variation in the pattern of childhood mortality for most of the countries and sub-national regions considered.

As Southern Africa is least affected by these impediments to the construction of "regional" life tables, one can attempt to construct models for this part of the continent. They are then applied to a country whose data are not included in the construction of the life table but that is believed to manifest the same pattern of mortality in childhood. Figures 7.2 - 7.7 show that Namibia, Zimbabwe and South Africa display similar "underlying" patterns of childhood mortality, as well as levels of $\gamma$ that do not greatly differ from each other. Using all the DHS birth histories from these three countries and the Princeton “North” Level 15-life table for both sexes as a standard and again including only statistically significant second order time-related variables in the model, the same three-parameter model was fitted to the combined data. This yields the following coefficients for the constituent parameters:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $\lambda_0$ | = | 0.60195 | $\lambda_p$ | = | 1.57691 | $\lambda_h$ | = | 0.62880 |
| $\lambda_t$ | = | -0.00613 | $\lambda_{p \cdot t}$ | = | 0.00960 | $\lambda_{h \cdot t}$ | = | -0.00327 |
| $\lambda_T$ | = | — | $\lambda_{p \cdot T}$ | = | -0.00095 | $\lambda_{h \cdot T}$ | = | — |

These coefficients are used accordingly to derive a Southern African Regional Life Table intended to be representative of the mortality experiences of the three countries on whose data it is based. The life tables from birth to age 20 years for the region for 1970, 1980 and 1990 are shown in Table 8.3.

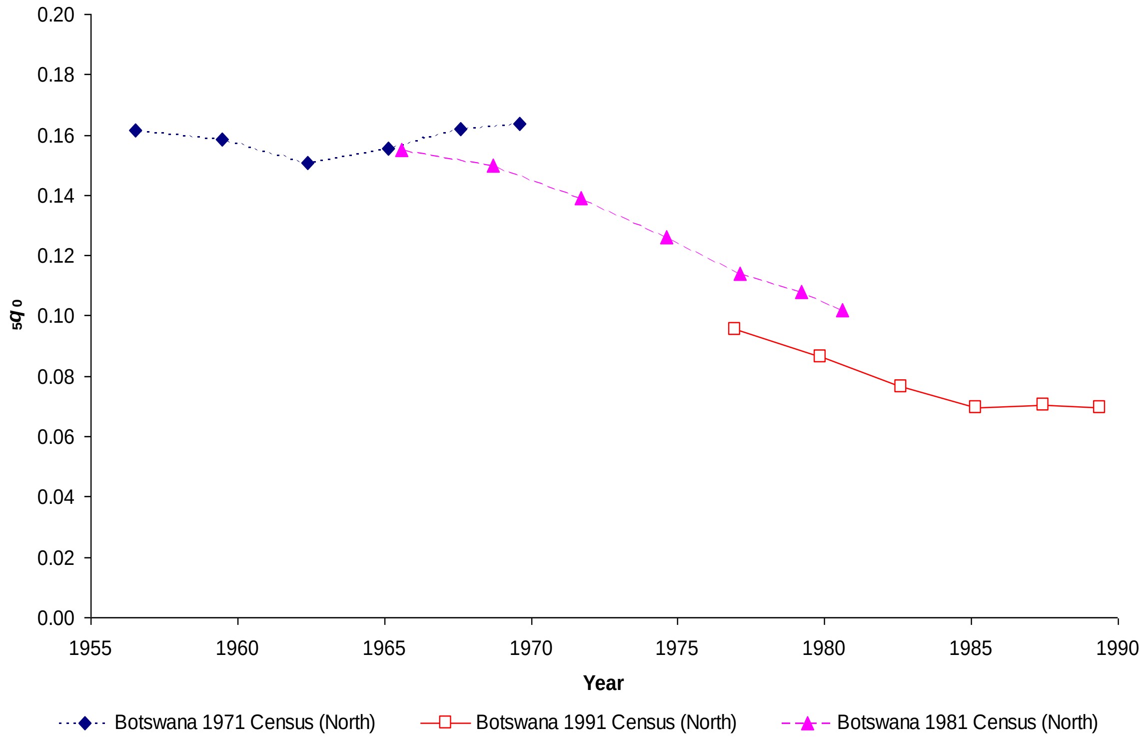
As Botswana is surrounded by these three countries it is likely to have a similar pattern of mortality. A test of appropriateness of the derived "regional" life table for Botswana is conducted in the form of indirect estimation of under-5 mortality using the Botswanan 1971, 1981 and 1991 census data. Figures 5.4 and 5.11 in Chapter 5 suggest that Botswana had a Princeton “North” pattern of mortality in childhood in terms of the relationship between infant and child mortality levels. For this reason, indirect estimates are first derived from each of the datasets using the Princeton "North" pattern of mortality, and then compared with each other. The information on proportions dead of children ever born from the 1981 census was not available to the author for indirect estimation of ${}_5q_0$ using the derived 1980 Southern African “Regional” life table. The results are shown graphically in Figure 8.4. The 1981 census-based estimates are included in the second panel for completeness despite having been derived using the “North” model pattern. It is apparent from the two graphs that, even if the

**Table 8.3:** ***Derived Southern African "Regional" life tables from birth to age 20 years for 1970, 1980 and 1990 based on data from Zimbabwe, Namibia and South Africa.***

| Age (*in yrs*) | 1970 | | 1980 | | 1990 | |
|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.42030 | 1.00000 | 0.27408 | 1.00000 | 0.22798 | 1.00000 |
| 0.0833 | 0.20963 | 0.96558 | 0.11611 | 0.97742 | 0.09144 | 0.98118 |
| 0.25 | 0.10634 | 0.93242 | 0.05023 | 0.95868 | 0.03750 | 0.96634 |
| 0.5 | 0.12504 | 0.90796 | 0.05065 | 0.94672 | 0.03514 | 0.95732 |
| 0.75 | 0.08733 | 0.88001 | 0.03252 | 0.93481 | 0.02193 | 0.94895 |
| 1 | 0.06626 | 0.86101 | 0.02312 | 0.92724 | 0.01526 | 0.94376 |
| 1.25 | 0.04458 | 0.84686 | 0.01417 | 0.92189 | 0.00907 | 0.94017 |
| 2 | 0.01371 | 0.81901 | 0.00400 | 0.91215 | 0.00254 | 0.93380 |
| 3 | 0.00988 | 0.80787 | 0.00267 | 0.90850 | 0.00166 | 0.93143 |
| 4 | 0.00725 | 0.79992 | 0.00182 | 0.90608 | 0.00110 | 0.92988 |
| 5 | 0.00366 | 0.79414 | 0.00079 | 0.90442 | 0.00045 | 0.92886 |
| 10 | 0.00181 | 0.77972 | 0.00033 | 0.90088 | 0.00018 | 0.92677 |
| 15 | 0.00229 | 0.77269 | 0.00044 | 0.89940 | 0.00024 | 0.92595 |
| 20 | 0.00324 | 0.76391 | 0.00068 | 0.89743 | 0.00038 | 0.92483 |

1981 census-based estimates are excluded from the picture, the derived Southern African "Regional" pattern of mortality yields estimates that depict a more consistent and plausible trend in $_5q_0$ in Botswana than does the Princeton "North" model of mortality. On this basis, one can infer that the derived "regional" life tables for childhood and early adulthood based on Zimbabwean, Namibian and South African data reflect Botswanan mortality experience reasonably well.

In order to determine the effect of heterogeneous "underlying" mortality patterns and $\gamma$-values on similar estimates, a set of examples are explored in West Africa focussing on The Gambia. The country is part of the Sahel region of West Africa and is surrounded on three sides by Senegal. Figures 7.2 - 7.4 show that the three Senegalese sub-national regions bordering The Gambia had consistently different "underlying" patterns of mortality over the periods concerned. Although the regions had $\gamma$-values that were similar in 1985 and 1995, Senegal has



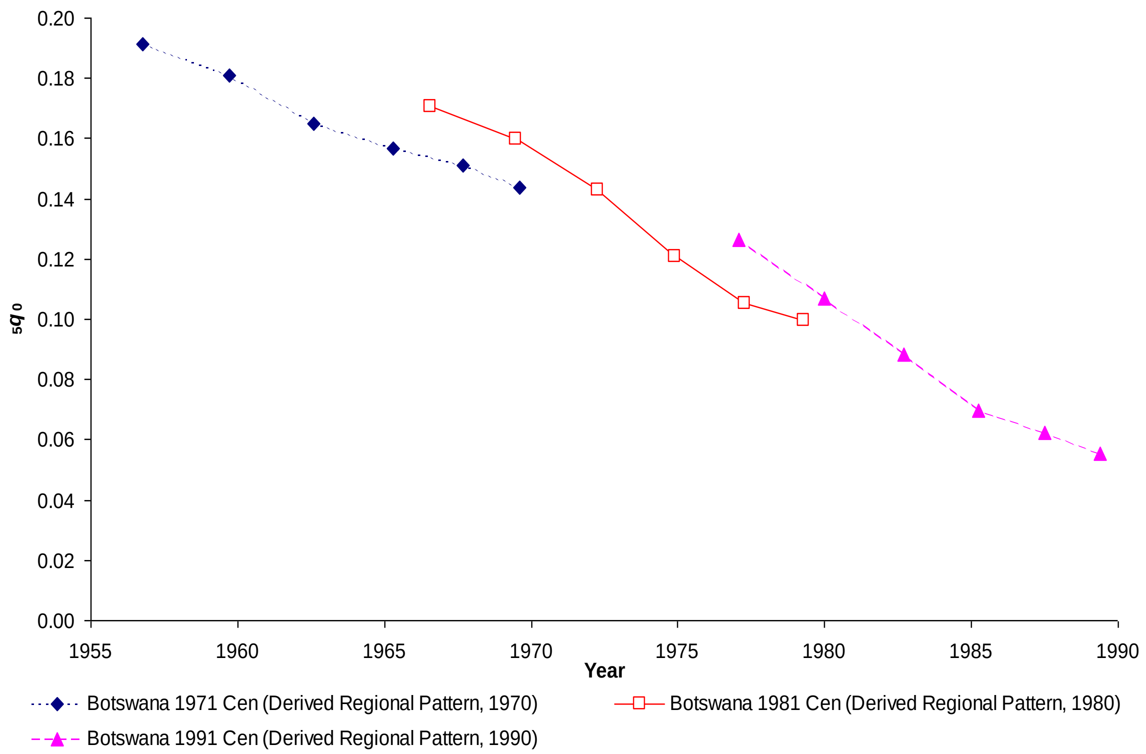




**Figure 8.4:** ***Comparison of indirect estimates of $_5q_0$ for Botswana obtained using the Princeton "North" pattern against those obtained using the Derived Regional Pattern based on South African, Zimbabwean and Namibian data.***

heterogeneous age patterns of mortality and the pattern in The Gambia is unknown. Equally, the Sahel region and the whole of West Africa represent larger geographical areas that contain even more varied mortality patterns. Using life tables derived from each case to estimate ${}_5q_0$ for The Gambia is expected to give an indication as to the degree to which inappropriate parameters can cause a regionally derived set of life tables to bias estimates for some constituent populations. The models fitted to the data from the entire Sahel region and West Africa yielded the parameter constituent coefficients shown in Table 8.4. The corresponding life tables are presented in Tables 8.5 and 8.6.

**Table 8.4:** ***Coefficients of parameter constituents obtained from models fitted to the Sahel region and the whole of West Africa.***

| Parameter | | Sahel Region | West Africa |
|---|---|---|---|
| *α-related:* | $\lambda_0$ | 0.48413 | 0.56894 |
| | $\lambda_t$ | -0.01518 | -0.02547 |
| *β-related:* | $\lambda_p$ | 1.05506 | 1.13629 |
| | $\lambda_{p \cdot t}$ | 0.00163 | -0.00179 |
| *γ-related:* | $\lambda_h$ | 0.58510 | 0.52524 |
| | $\lambda_{h \cdot t}$ | 0.00832 | 0.00550 |

Using the relevant data from the 1971, 1981 and 1991 censuses of The Gambia, ${}_5q_0$ estimates were derived first using the Princeton "North" coefficients and pattern of mortality, which was selected on the basis that Senegalese infant-to-child mortality relationship is even more extreme than "North" (see Figures 5.1 and 5.11). This was followed by similar estimations using the appropriate derived national life tables for Senegal (see Appendix 8), and the Sahel and West Africa "Regional" life tables. The four sets of estimates are compared graphically in Figure 8.5. The trends in ${}_5q_0$ obtained from estimates based on the Senegalese and Sahel life tables appear consistent, especially those from the 1981 and 1991 censuses. The estimates

**Table 8.5:** ***Derived Sahel "Regional" life tables from birth to age 20 years for 1970, 1980 and 1990.***

| Age (*in yrs*) | 1970 | | 1980 | | 1990 | |
|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.54463 | 1.00000 | 0.45829 | 1.00000 | 0.38563 | 1.00000 |
| 0.0833 | 0.30248 | 0.95562 | 0.25217 | 0.96253 | 0.21023 | 0.96837 |
| 0.25 | 0.17041 | 0.90863 | 0.14079 | 0.92290 | 0.11631 | 0.93503 |
| 0.5 | 0.17459 | 0.87073 | 0.15568 | 0.89098 | 0.13882 | 0.90823 |
| 0.75 | 0.12890 | 0.83353 | 0.11439 | 0.85697 | 0.10151 | 0.87724 |
| 1 | 0.10206 | 0.80710 | 0.09024 | 0.83281 | 0.07978 | 0.85526 |
| 1.25 | 0.07300 | 0.78677 | 0.06420 | 0.81423 | 0.05647 | 0.83837 |
| 2 | 0.03015 | 0.74484 | 0.02424 | 0.77594 | 0.01948 | 0.80360 |
| 3 | 0.02287 | 0.72272 | 0.01830 | 0.75736 | 0.01465 | 0.78810 |
| 4 | 0.01760 | 0.70638 | 0.01403 | 0.74363 | 0.01118 | 0.77663 |
| 5 | 0.00988 | 0.69405 | 0.00781 | 0.73327 | 0.00617 | 0.76800 |
| 10 | 0.00545 | 0.66058 | 0.00426 | 0.70519 | 0.00333 | 0.74468 |
| 15 | 0.00663 | 0.64283 | 0.00520 | 0.69032 | 0.00408 | 0.73237 |
| 20 | 0.00891 | 0.62187 | 0.00703 | 0.67259 | 0.00554 | 0.71756 |

**Table 8.6:** ***Derived West Africa "Regional" life tables from birth to age 20 years for 1970, 1980 and 1990.***

| Age (*in yrs*) | 1970 | | 1980 | | 1990 | |
|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.58384 | 1.00000 | 0.46307 | 1.00000 | 0.36728 | 1.00000 |
| 0.0833 | 0.30064 | 0.95250 | 0.24090 | 0.96214 | 0.19304 | 0.96985 |
| 0.25 | 0.15732 | 0.90594 | 0.12733 | 0.92427 | 0.10305 | 0.93915 |
| 0.5 | 0.14974 | 0.87100 | 0.12902 | 0.89531 | 0.11117 | 0.91526 |
| 0.75 | 0.10632 | 0.83899 | 0.09210 | 0.86689 | 0.07977 | 0.89017 |
| 1 | 0.08170 | 0.81698 | 0.07105 | 0.84716 | 0.06179 | 0.87259 |
| 1.25 | 0.05597 | 0.80046 | 0.04896 | 0.83224 | 0.04283 | 0.85922 |
| 2 | 0.02227 | 0.76755 | 0.01858 | 0.80223 | 0.01550 | 0.83205 |
| 3 | 0.01631 | 0.75065 | 0.01367 | 0.78747 | 0.01146 | 0.81926 |
| 4 | 0.01214 | 0.73850 | 0.01022 | 0.77678 | 0.00860 | 0.80992 |
| 5 | 0.00633 | 0.72960 | 0.00538 | 0.76888 | 0.00458 | 0.80299 |
| 10 | 0.00323 | 0.70687 | 0.00277 | 0.74847 | 0.00238 | 0.78482 |
| 15 | 0.00403 | 0.69555 | 0.00345 | 0.73815 | 0.00296 | 0.77552 |
| 20 | 0.00563 | 0.68167 | 0.00480 | 0.72552 | 0.00409 | 0.76414 |

obtained using the West Africa "Regional" life tables seem somewhat less appropriate, since the $_5q_0$ levels for the most recent periods appear to be slightly under-estimated. Notwithstanding this, the West Africa "Regional" life tables represent Gambian mortality experience much better than the Princeton "North" model of mortality. Thus in instances where a country's pattern of mortality in childhood is unknown, that a neighbouring or adjacent country included in this study is likely to be applicable. For instance, the childhood mortality pattern prevalent in Sierra Leone could be inferred from that of Guinea. Unfortunately, while the Sahel "Regional" life tables may have reasonably represented Gambia's mortality pattern, it is not necessarily appropriate for all populations within this part of the continent. For it to be used with confidence as a "regional" life table, the differences between the life tables of the constituent sub-national regions would need to be small. They are not.

This example demonstrates, therefore, that despite the variations observed in prevailing "underlying" patterns of mortality in childhood and sizes of the "hump" of excess mortality within the first two years of life, there are prospects for the generation of African model life tables for different parts of the continent. The construction, however, will be cumbersome because they need to reflect changes in mortality over time. Nevertheless, despite the difficulty of demarcating regions of Africa with homogeneous age patterns of mortality, standard life tables based on African data are likely to be more appropriate than existing models based on historical European data.

It is worthwhile at this point to compare the Hypothetical West African (HWA) model developed by the United Nations (1982a), and discussed in Chapter 3, with the derived Sahel and West Africa "Regional" life tables. This is done in Figure 8.6 using survivorship curves, $l(x)$, between birth and age 5 years. It should be noted, though, that the HWA models for both males and females depict specific life expectancies at birth, $e(x)$, while those of the derived Sahel and West Africa "Regions" are time-specific life tables. Whilst the survivorship schedules of all three sets of life tables show more or less similar forces of mortality within the first year of life, significant differences emerge from the second year of life. For both sexes, the Hypothetical West African life tables are characterised by relatively heavier mortality than the derived Sahel and West Africa "Regional" patterns, after age 2 years. This implies that for given levels of $_1q_0$, the Hypothetical West African model is expected to yield

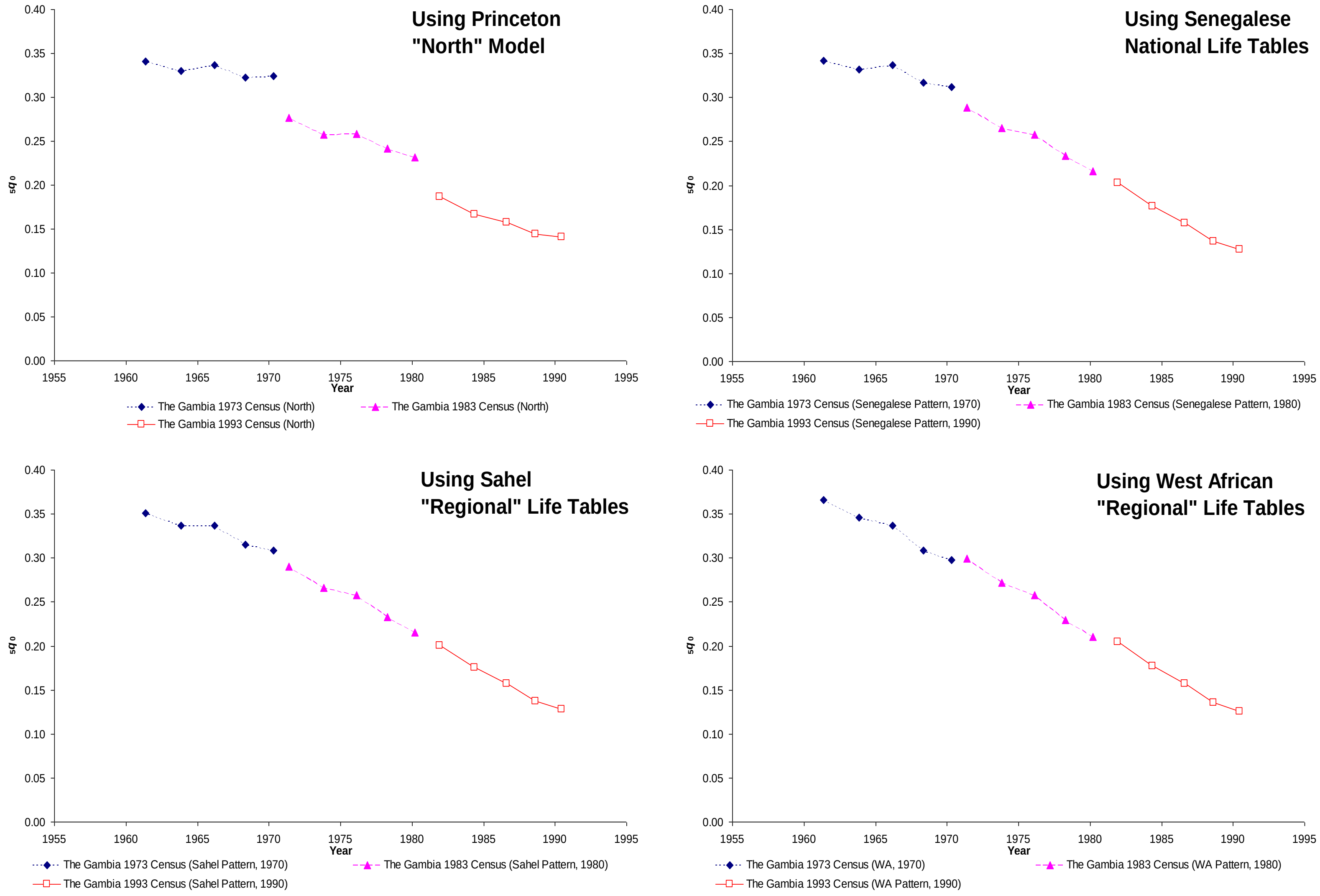



**Figure 8.5:** ***Comparison of indirect estimates of $_5q_0$ for The Gambia obtained using the Princeton "North" pattern against those obtained using the Senegalese relational life tables, and the derived Sahel and West Africa "Regional" life tables for 1970, 1980 and 1990.***

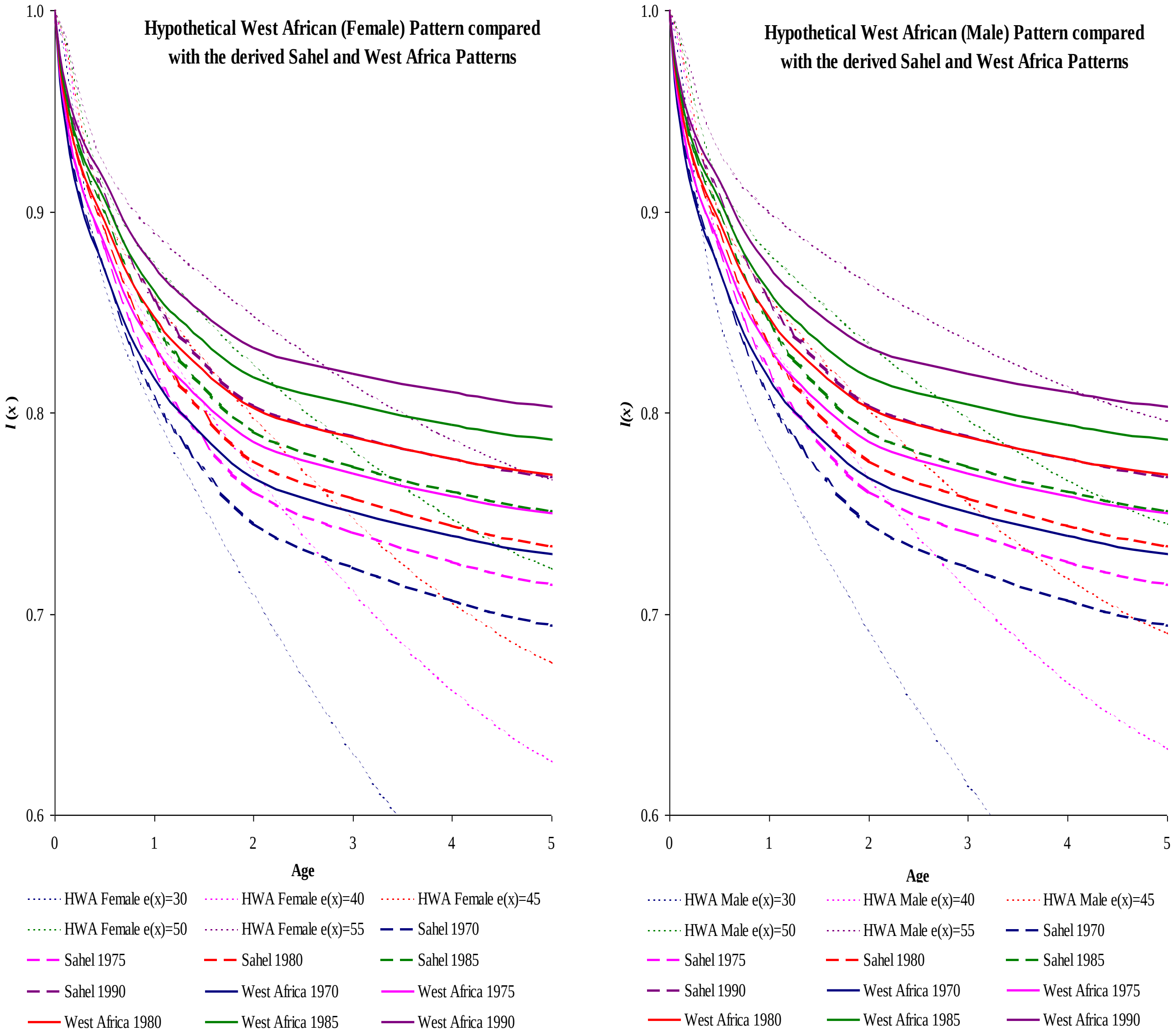



**Figure 8.6:** ***Comparison of the survivorship curve of the United Nation's (1982a) Hypothetical West African model life table against those of the derived Sahel and West Africa "Regional" patterns.***

higher levels of ${}_4q_1$ than the derived Sahel and West Africa patterns. This suggests that the data on which the Hypothetical West African model is based is not representative of the overall childhood mortality experience of the Sahel region. As far as the two new "Regional" time-specific life tables are concerned, those of the Sahel region consistently depict higher levels of ${}_4q_1$ than the tables of the West Africa region with much of the excess being concentrated in the second year of life. This confirms the widely reported fact that child mortality levels are distinctively higher in the Sahel region than any other part of the continent (Blacker *et al.*, 1985; Hill, 1995).

## 8.5 Conclusion

Since the results that have emanated from the main analysis of this chapter and that of the previous one differ from expectations, their credibility and plausibility will undoubtedly be subjected to scrutiny. The most probable approach for this is to subject the derived national and sub-national parameters and life tables to a series of demographic tests. Also, determining the most appropriate values of ${}_{n}a_{x}$ for each age group for the region or country of interest may yield greater precision with respect to the life tables as well as their applications to various demographic procedures. However, if the presented examples of Burkina Faso, Malawi, Botswana and The Gambia are anything to go by, they clearly attest to the following:

- The presented national life tables represent the pattern of mortality in childhood in their respective countries and at the indicated times better than any existing life table or model system of life tables.

- The childhood mortality situation in the continent is still dynamic which is an indication of a transition in progress, or instability brought about by worsening conditions in relation to the determinants of childhood mortality in specific countries. In fact, it is likely that as long as huge disparities exist between regions of the same country and between countries in the continent with respect to economic, environmental and health indicators, the childhood mortality situation will continue to display erratic properties.

- The generation of African "regional" mortality standards in the form of time-specific life table — at least in childhood and early adulthood — is an imminent demographic reality.

# Chapter 9

# Conclusions

Inaccurate measurements of demographic indicators necessarily imply a great potential for inaccurate policy recommendations, thereby leading to formulation and implementation of health or social interventions that will seek the wrong targets and eventually get deemed ineffective. The measurement of childhood mortality indicators for use in the design and evaluation of child survival programmes is no exception to this assertion. It appears, though, that improvements in childhood mortality research in Sub-Saharan Africa depend on the volume and quality of the relevant data available. The more accurate and widely representative the data become, the higher the chances for demographers to investigate with a greater degree of confidence and understand the underlying characteristics of childhood mortality in the continent, especially the age pattern. However, the outlook — at least for the foreseeable future — for the state of demographic data in the continent is not any different from what presently obtains. High costs associated with the institution of more robust methods of data collection appear to be beyond the reach of the bulk of African countries currently plagued with stagnant or declining economies. As a result, DHS birth histories will continue to be the main source of data for childhood mortality research in the continent. They have limitations though, especially in relation to HIV/AIDS. Despite the high sero-prevalence in Eastern and Southern Africa, it is difficult to attribute observed reversals of the decline in childhood mortality levels in Eastern and Southern Africa to the AIDS epidemic. As far as DHS surveys are concerned, the information used in the estimation of childhood mortality indicators and assessment of mortality patterns is obtained from mothers who are alive at the time of the respective national interviews — be they HIV-positive or negative. Mothers most affected by AIDS-related childhood mortality are likely to have died prior to the survey, or may be too ill to be included although such a bias has never been reported or known to been investigated anywhere. Therefore, the DHS may probably be capturing very few AIDS-related childhood deaths from HIV-positive mothers who were alive at the time of the survey. Also, AIDS-related childhood deaths — both direct and indirect — among orphans in the general population are not captured in the birth histories. Collectively, these problems perhaps explain the disparity between the findings of Adetunji (2000) and the rather gloomy scenario in

Eastern and Southern Africa portrayed by Ntozi and Nakanaabi (1997), Foster (1997; 1998) and Boerma *et al*. (1998) from recent community studies.

This thesis set out to shed light on and fill some of the gaps of demographers' knowledge and understanding of the types, distributions and characteristics of mortality patterns within childhood in contemporary Sub-Saharan Africa. Attention was specifically focussed on establishing the true childhood mortality patterns and the extent to which they vary across the continent. Their representation in the form of life tables was also pursued, thus paving the way for improvements in the measurement of ${}_5q_0$ especially, and their application in the modelling of other demographic processes such as population projections for national or sub-national development planning purposes.

The analysis in Chapter 5 showed that on the basis of infant-to-child mortality relationships, more than 75% of sub-national regions in West and Central Africa, and about 50% of regions in Eastern and Southern Africa display childhood mortality patterns outside the range of the Princeton system. They are characterised by higher child mortality relative to infant mortality than would be expected of the Princeton "North" pattern, thus giving a strong indication that the greater part of the continent experiences a pattern of childhood mortality unique to the region. Although the same approach to the assessment of mortality patterns reveals that Eastern and Southern African sub-national regions are more likely to display a Princeton pattern than other parts of the continent, the results of the chapter — especially the distributions mapped in Figure 5.11 — show that such an extreme pattern of mortality is not restricted to West Africa as suggested by earlier studies (Blacker *et al*., 1985; Hill, 1995). Using sub-national regions as unit of analysis, this thesis has succeeded in mapping out the distribution of prevailing patterns of childhood mortality across Sub-Saharan Africa, thereby allaying the sense of uncertainty as to what childhood mortality patterns prevail in specific parts of the continent on which Blacker *et al*. (1985) and Hill (1995) could only speculate. Notwithstanding these contributions to demographers' understanding of Sub-Saharan African mortality in childhood, the extent to which the Princeton system falls short of adequately describing the childhood mortality experiences of half the sub-national regions considered raises some methodological concerns. This is because such countries, by virtue of their poor track records of demographic data collection, depend on estimation techniques that utilise model mortality patterns, with the Princeton system being the one most commonly used.

An investigation based on the age-specific mortality schedule in childhood links the unusual pattern of high child mortality relative to infant mortality to a "hump" of excess mortality in the late post neo-natal period and the second year of life. The analysis in chapter 6 shows how the different types of this feature affect the aggregate measure of $_4q_1$ relative to $_1q_0$ and consequently the observed pattern of childhood mortality on the basis of infant-to-child mortality relationships, potentially rendering it different from the Princeton model patterns. Although Cantrelle and Leridon (1971) and Hill *et al*. (1983) hinted that the observed "hump" of excess mortality in the first two years of the age-specific mortality schedules of the populations they considered may be confined to Western Africa, Chapter 6 further demonstrated that the feature is widely prevalent and is found in every part of the continent, even in low mortality countries.

Upon identifying the "hump" as an integral part of childhood mortality patterns in Sub-Saharan Africa, an appropriate 3-parameter relational model that controls for it between the ages 6 and 24 months was specified and fitted to the data to describe the mortality trends of the 26 countries considered and their respective sub-national regions. The fitted models form the basis for the exploration of the prospects of representing the true national and sub-national childhood mortality patterns that prevail in the form of smoothed life tables using the Princeton "North" model level 15 for both sexes (with sex ratio at birth of 1.03) as standard. They also reveal that between the within the age brackets 0-5 months and 24-59 months, mortality characteristics fall within the Princeton range for most sub-national regions, especially in recent periods. The smoothed national life tables generated are proposed for use in demographic estimation and modelling processes in for the countries they relate to. In the case of the indirect estimation of national $_5q_0$, they can be employed with correction factors and time location coefficients associated with Princeton “North”. Application of some of them has shown that they yield better trends in $_5q_0$ estimates than the Princeton model patterns which are based on historical European data. Sub-national life tables can be generated using the available relevant parameter estimates. They will prove to be useful in situations where life tables are required for specific communities in a region of a country; or in formulation and evaluation of micro-level child survival projects. This thesis perhaps heralds the introduction of an element of precision into the inexact science of African mortality studies.

Despite the strides this thesis has taken in African childhood mortality research, some questions remain unanswered. The most significant is the force beneath the distribution of childhood mortality patterns revealed by this study to be prevailing in populations of the continent. Recall from Chapter 1 that the determinants of mortality in Africa are believed to operate through two main classificatory variables, i.e. region of residence and ethnicity. Whether the inclusion of ethnicity in the analysis would have yielded a similar distribution of observed childhood mortality patterns is not readily evident. However, an intensive national study in an ethnically diverse country may be able to shed light on this.

To take the work contained in this thesis further, future research can be focused on the following:

- The development of new correction factors and time location coefficients for use with any constructed life table — national or "regional" — for the estimation of under-5 mortality using Brass's technique. Those associated with the Princeton "North" pattern can be used in the meantime.

- The possibility of modifying the three-parameter model adopted in this study to a five-parameter one can be explored to cater adequately for, as well as ensure flexibility in, the start and end points of the "hump" on age range.

- Attempts can be made to extend the generated national life tables to include adulthood, thereby producing complete life tables for the continent. There are three possible approaches to adopt, viz.:

    i. Assuming that the identified "underlying" patterns of mortality are true for all ages in the respective national populations concerned, complete life tables can then be generated in relation to Princeton "North" level 15 for both sexes using the derived national model parameters. This will essentially imply a fundamental assumption that the level of mortality in childhood for the population in question in relation to the standard life table is the same as that in adulthood for the same population and life table.

ii. A similar approach of in-depth investigation of mortality patterns as conducted in this study can be undertaken for adulthood in all the countries and sub-national regions covered by this study using sibling histories and other independent orphanhood data on which adult mortality estimates can be derived. The life tables that result from such an undertaking can be merged with the childhood and early adulthood life tables generated from the parameters presented in this study to yield complete life tables.

iii. The final opportunity presented by the results of this study is the possibility of constructing families of model life tables for childhood from all the life tables that can be derived from the parameters presented using an appropriate technique. There is the potential, though, for any system resulting from this approach to be criticised for having been based on smoothed data. Nevertheless, for a region so deprived of models of its own, the attempt may worth the criticism, and the models that come out of it can be linked with the model system of life tables for Sub-Saharan Africa that are being generated by the INDEPTH Network (INDEPTH Network, 2002).

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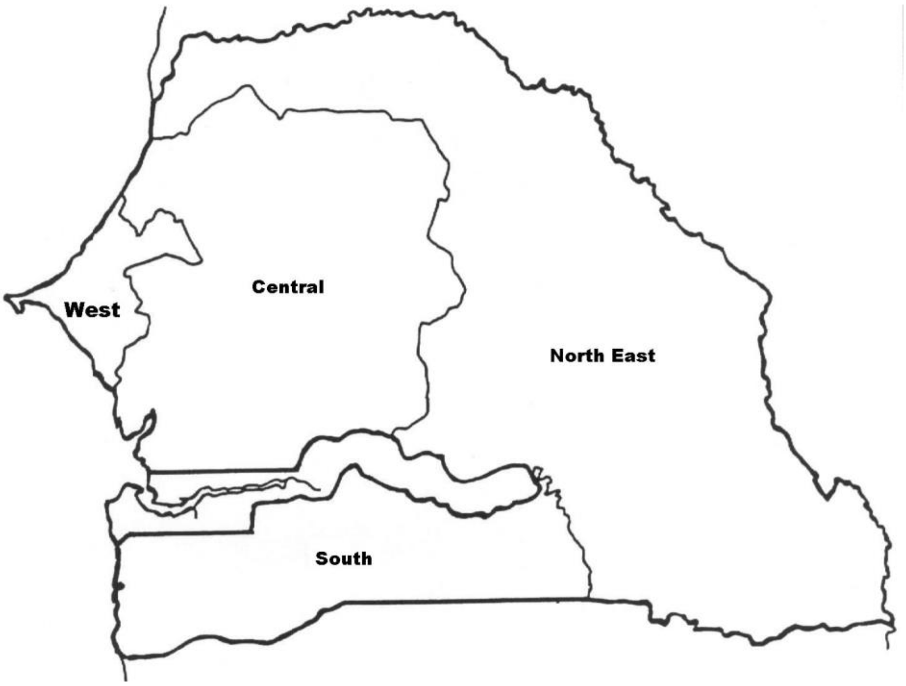
# Appendix 1

# Detailed Individual Country Maps

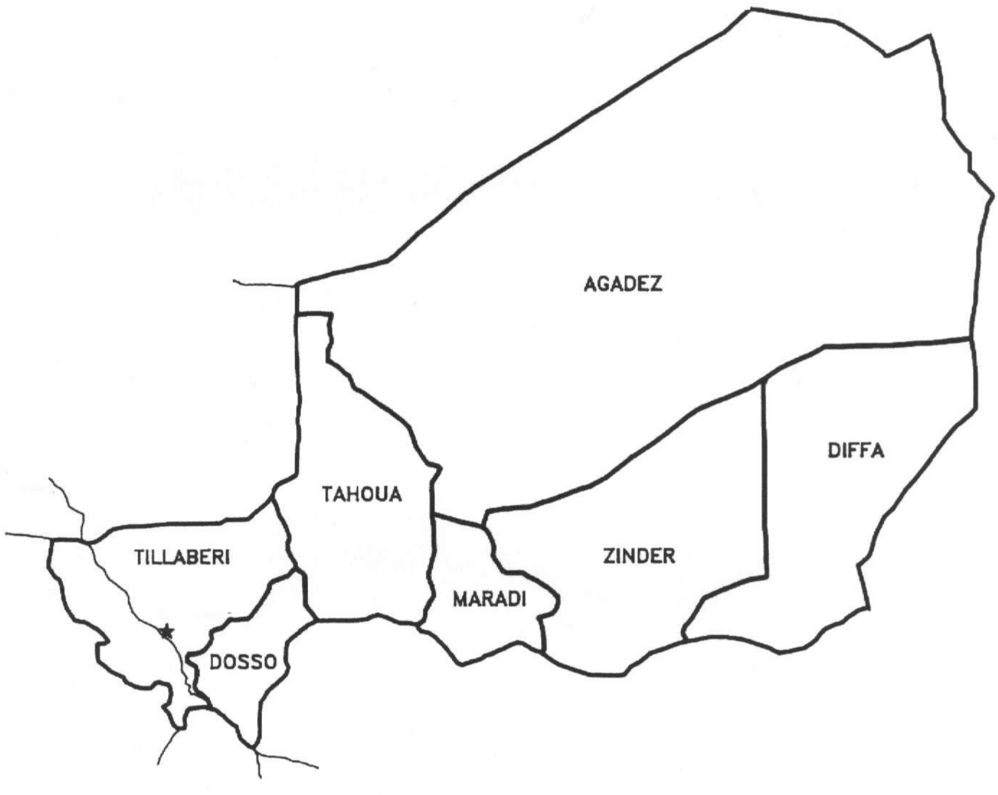
## Senegal




## Mali

# Burkina Faso

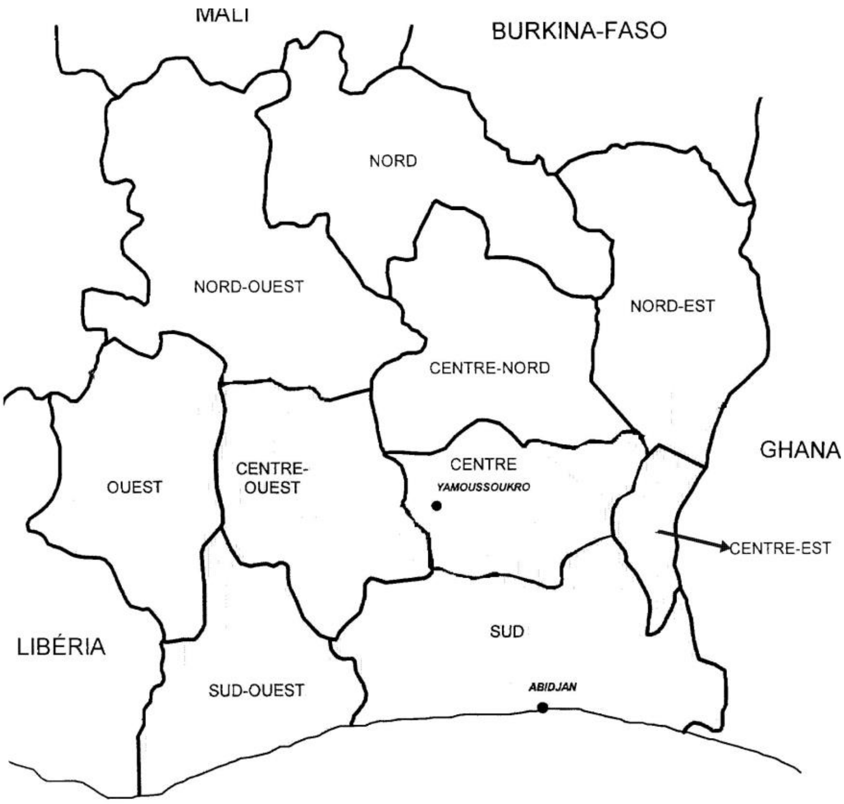

# Niger



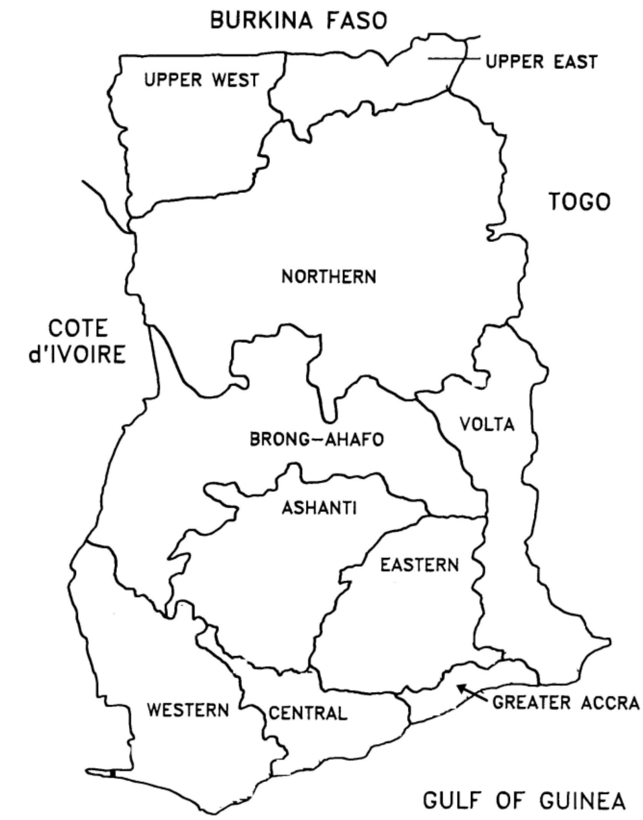
# Guinea


# Liberia

# Côte d'Ivoire



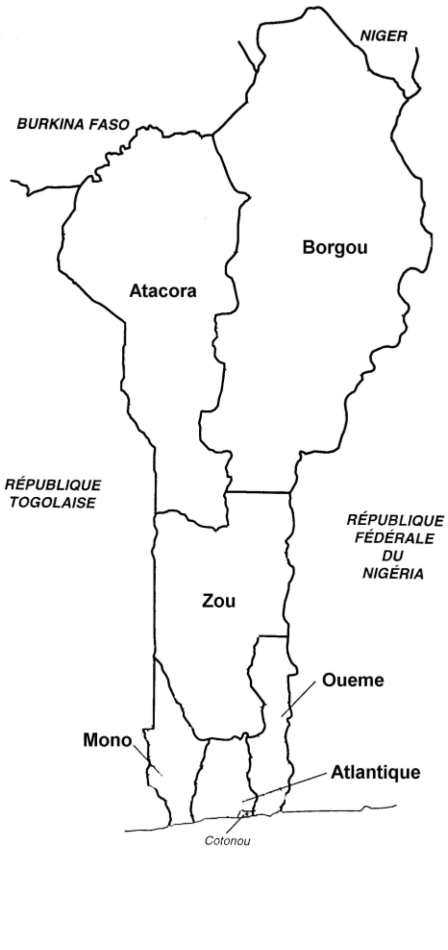

# Ghana



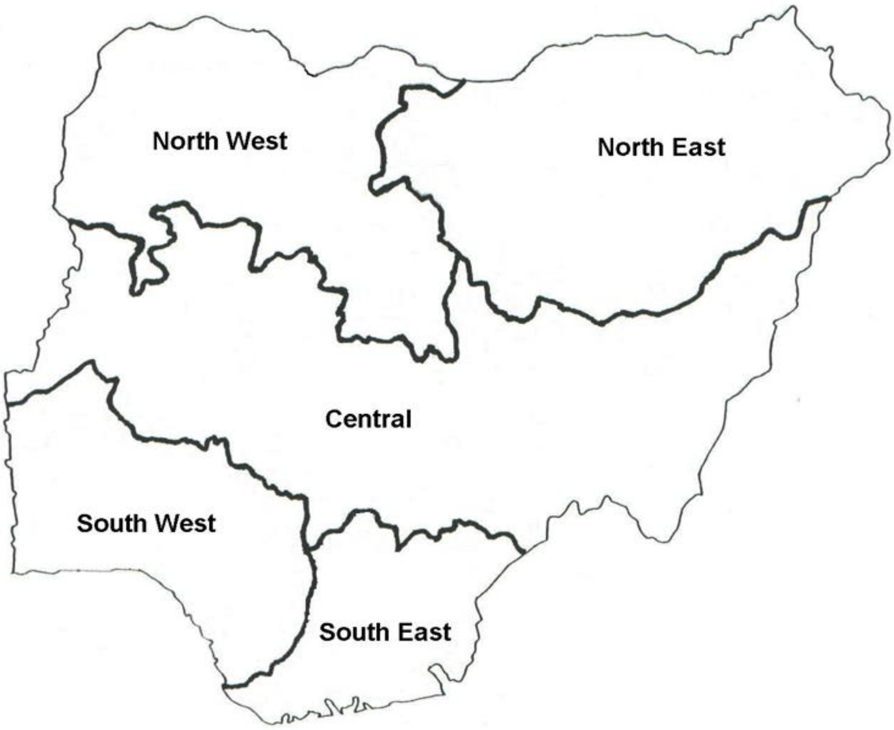
# Togo


BURKINA FASO
des Savanes
de la Kara
GHANA
Centrale
des Plateaux
Maritimes
LOME
OCEAN ATLANTIQUE

# Benin


NIGER
BURKINA FASO
Borgou
Atacora
RÉPUBLIQUE TOGOLAISE
RÉPUBLIQUE FÉDÉRALE DU NIGÉRIA
Zou
Oueme
Mono
Atlantique
Cotonou

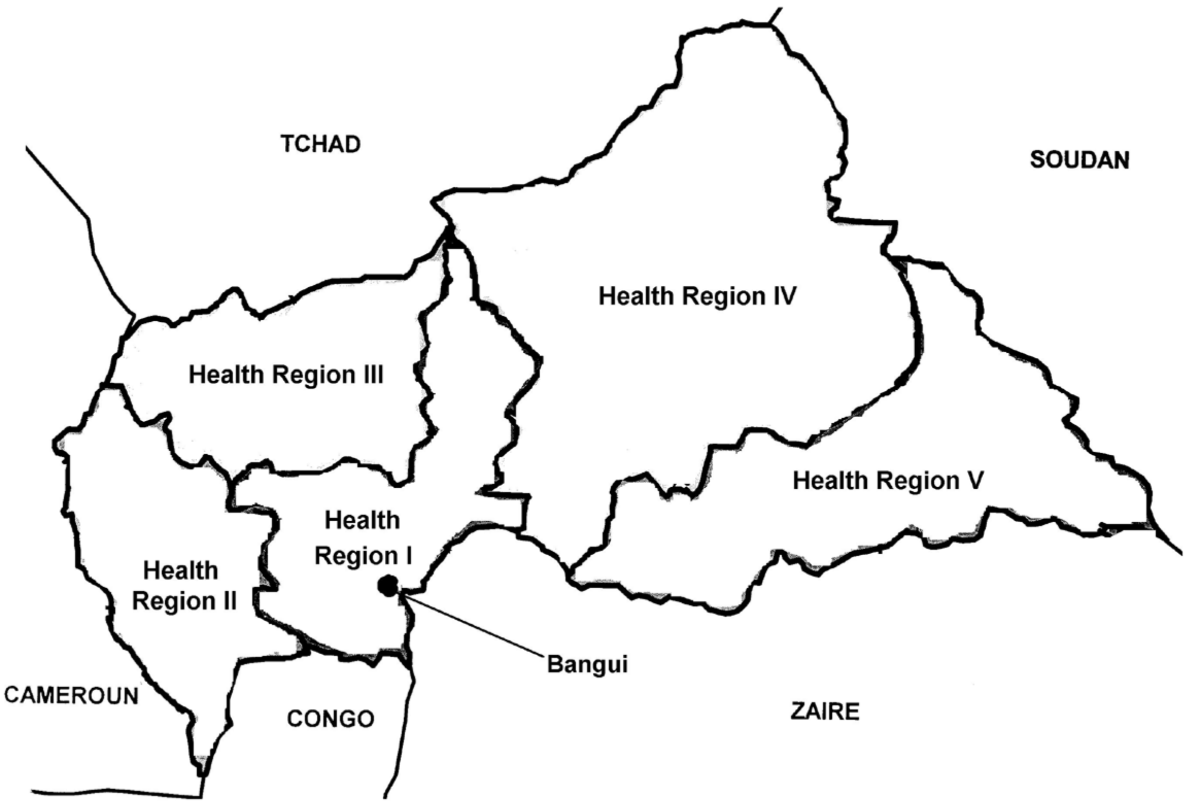
# Nigeria



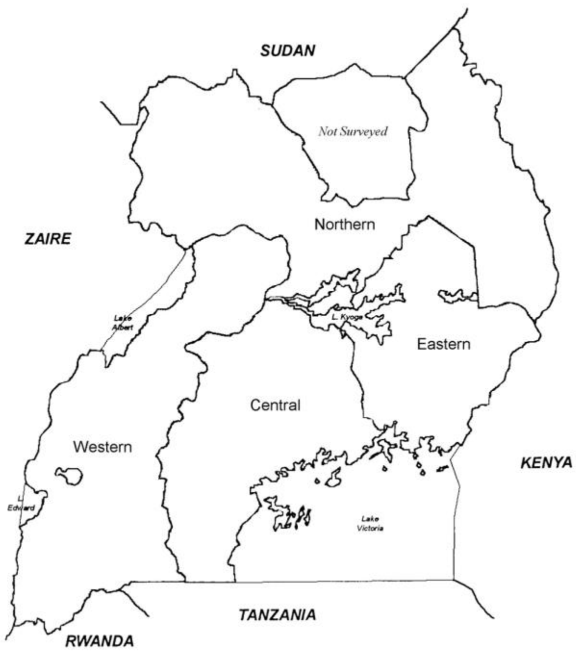

# Cameroon

# Chad

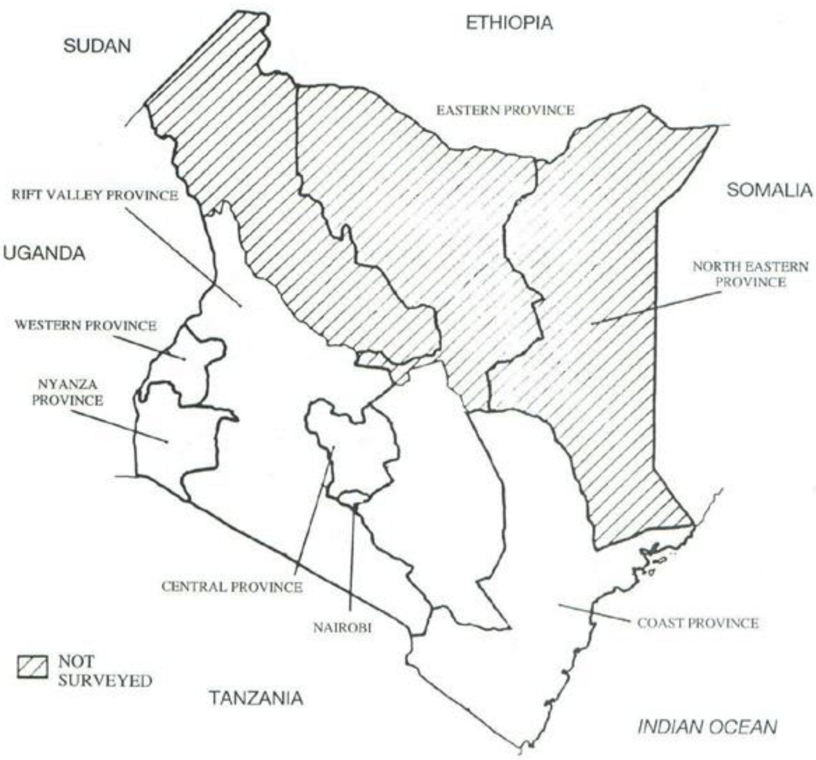

# Central African Republic



# Uganda




# Kenya



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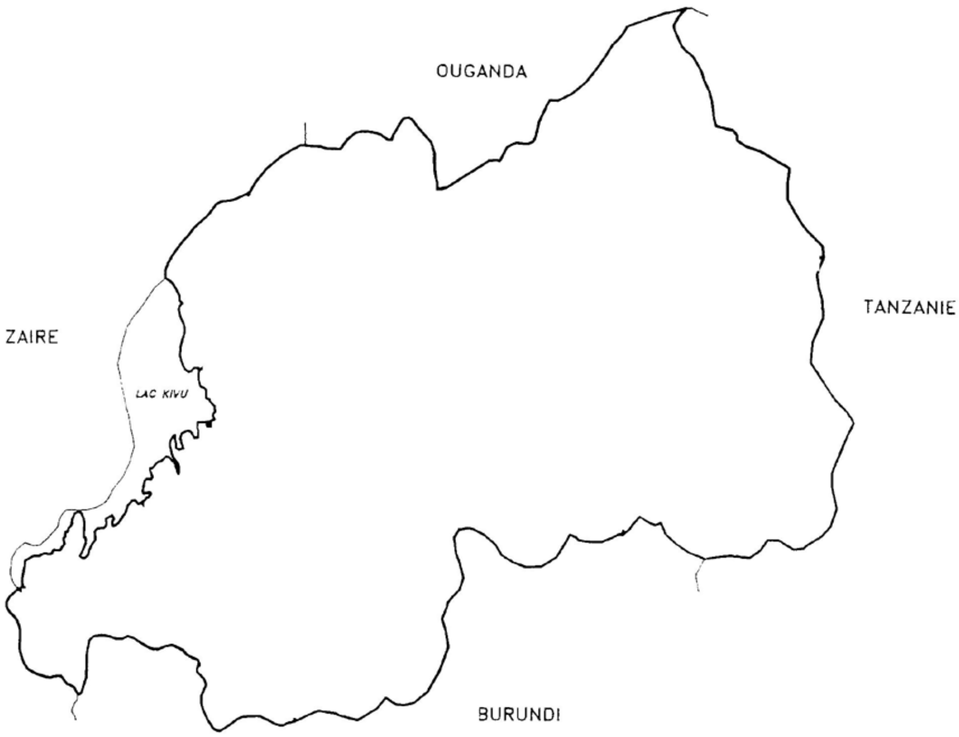


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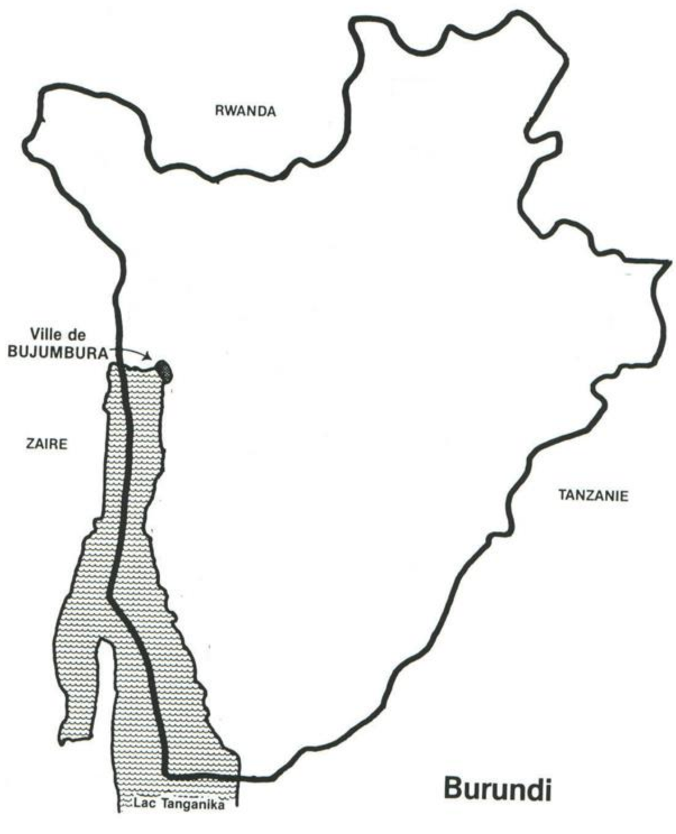

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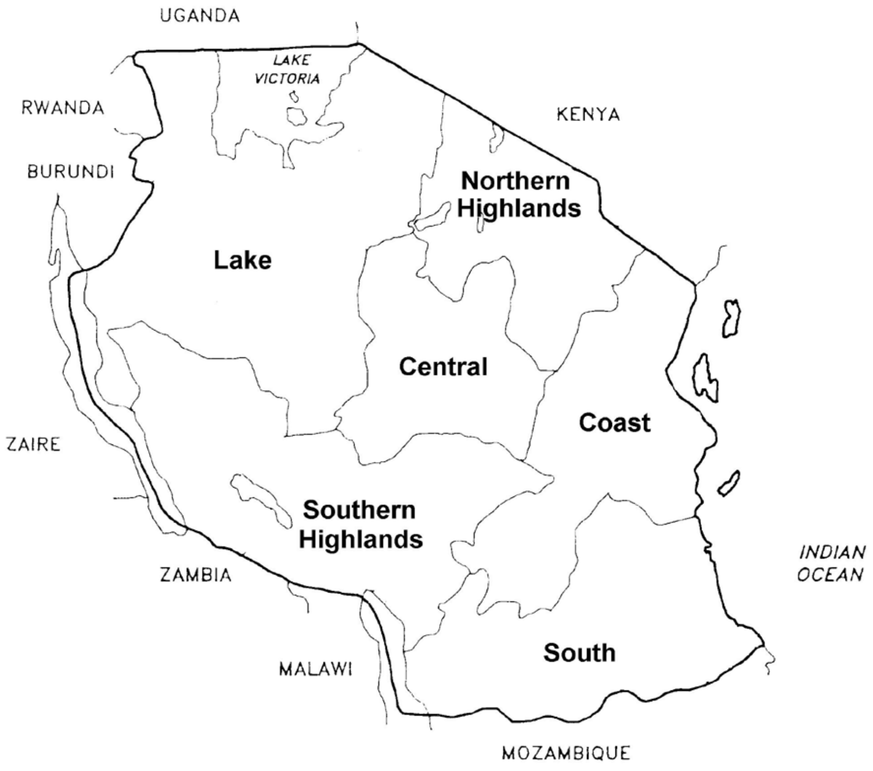
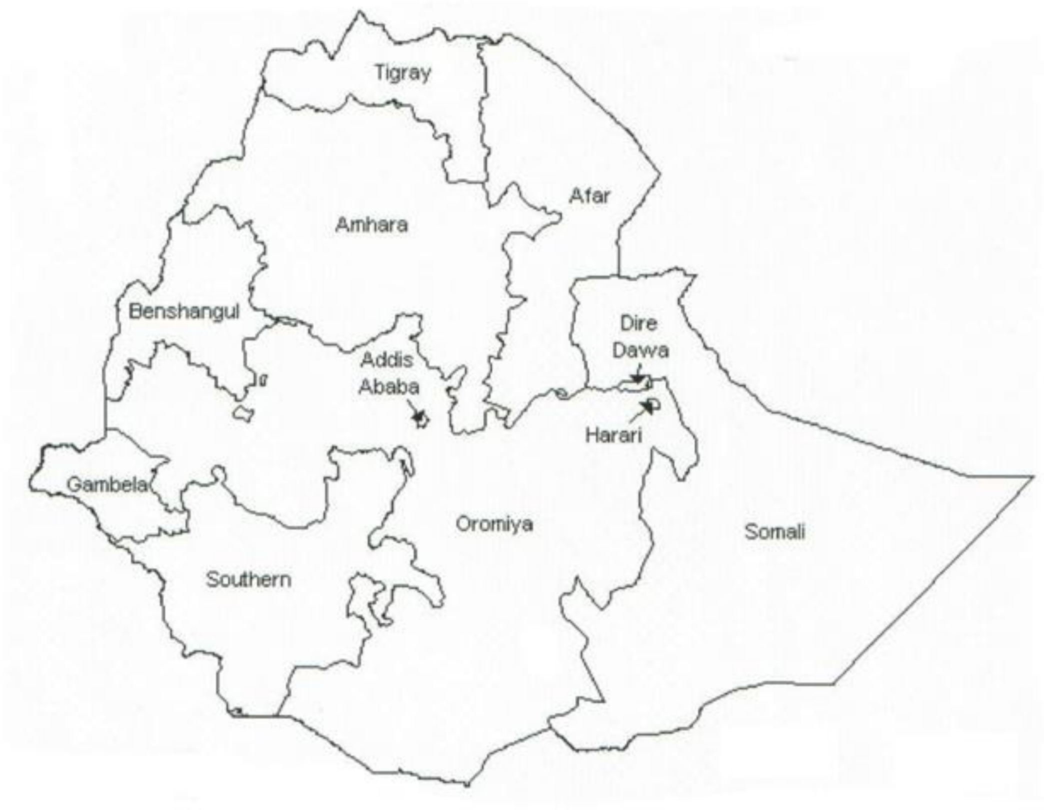
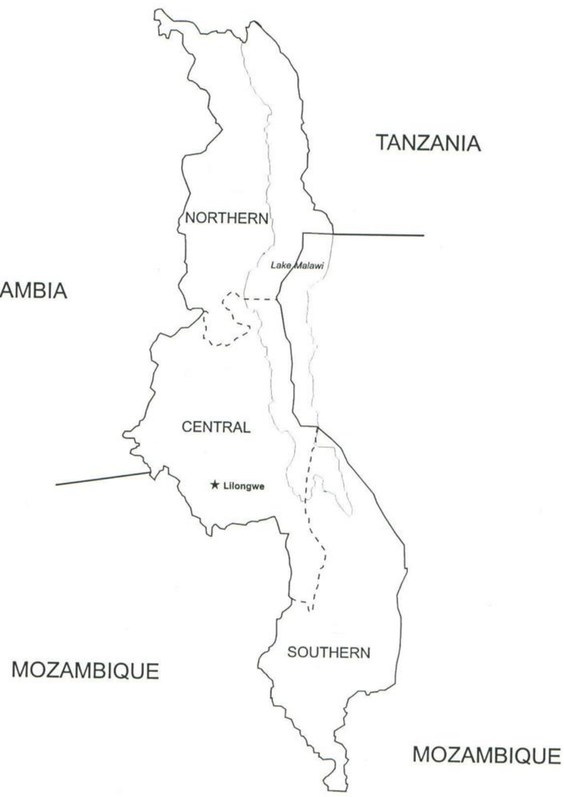



# Ethiopia



# Zambia


# Malawi



# Zimbabwe


# Mozambique

# Namibia


# South Africa

# Appendix 2

# Direct Estimates of Childhood Mortality Indicators from Birth Histories

**Senegal**

| **Period before Survey** | ***NNM*** | ***PNNM*** | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 1, 1986* | | | | | | | |
| 00-04 | 45.8 | 42.0 | 87.8 | 44.7 | 75.9 | 117.2 | 194.7 |
| 05-09 | 50.5 | 43.5 | 94.1 | 52.1 | 104.0 | 150.6 | 230.5 |
| 10-14 | 53.7 | 59.1 | 112.8 | 68.7 | 127.0 | 186.9 | 278.6 |
| 15-19 | 57.2 | 57.7 | 114.9 | 92.8 | 144.8 | 224.1 | 313.3 |
| 20-24 | 65.3 | 49.6 | 114.9 | 77.9 | 150.0 | 216.2 | 306.2 |
| *DHS 2, 1992* | | | | | | | |
| 00-04 | 34.4 | 33.2 | 67.6 | 22.8 | 46.5 | 68.2 | 131.2 |
| 05-09 | 46.5 | 37.8 | 84.3 | 39.6 | 72.3 | 109.0 | 184.1 |
| 10-14 | 43.4 | 46.5 | 89.9 | 43.6 | 78.3 | 118.5 | 197.7 |
| 15-19 | 49.6 | 49.2 | 98.8 | 56.0 | 126.9 | 175.9 | 257.3 |
| 20-24 | 58.4 | 61.4 | 119.8 | 74.9 | 134.7 | 199.5 | 295.4 |
| *DHS 3, 1997* | | | | | | | |
| 00-04 | 37.3 | 30.3 | 67.6 | 27.4 | 50.4 | 76.3 | 138.8 |
| 05-09 | 38.3 | 32.7 | 71.0 | 29.0 | 45.7 | 73.4 | 139.2 |
| 10-14 | 39.1 | 36.8 | 75.9 | 39.4 | 67.0 | 103.8 | 171.8 |
| 15-19 | 39.7 | 44.9 | 84.6 | 43.5 | 80.0 | 120.1 | 194.5 |
| 20-24 | 49.9 | 55.6 | 105.6 | 57.6 | 97.0 | 149.0 | 238.8 |

*NNM = Neonatal Mortality; PNNM = Post-neonatal Mortality.*

**Mali**

| **Period before Survey** | ***NNM*** | ***PNNM*** | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 1, 1987* | | | | | | | |
| 00-04 | 51.1 | 53.7 | 104.8 | 56.2 | 108.7 | 158.7 | 246.9 |
| 05-09 | 86.2 | 69.3 | 155.5 | 63.9 | 126.7 | 182.5 | 309.6 |
| 10-14 | 94.1 | 74.5 | 168.6 | 76.5 | 160.7 | 225.0 | 355.6 |
| 15-19 | 86.3 | 80.1 | 166.4 | 86.0 | 160.0 | 232.2 | 359.9 |
| 20-24 | 99.7 | 88.9 | 188.7 | 79.0 | 218.0 | 279.8 | 415.7 |
| *DHS 3, 1996* | | | | | | | |
| 00-04 | 60.3 | 62.1 | 122.4 | 48.7 | 86.7 | 131.2 | 237.5 |
| 05-09 | 76.4 | 68.2 | 144.5 | 48.0 | 101.2 | 144.3 | 268.0 |
| 10-14 | 82.4 | 69.3 | 151.7 | 59.6 | 111.4 | 164.4 | 291.2 |
| 15-19 | 88.5 | 69.7 | 158.2 | 61.6 | 133.3 | 186.7 | 315.4 |
| 20-24 | 94.8 | 89.0 | 183.9 | 70.3 | 155.6 | 215.0 | 359.3 |

**Burkina Faso**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 2, 1992* | | | | | | | |
| 00-04 | 43.2 | 50.5 | 93.6 | 43.2 | 62.3 | 102.8 | 186.8 |
| 05-09 | 59.8 | 61.9 | 121.8 | 49.1 | 69.4 | 115.1 | 222.8 |
| 10-14 | 64.1 | 58.4 | 122.5 | 54.3 | 85.3 | 135.0 | 241.0 |
| 15-19 | 75.4 | 64.9 | 140.3 | 69.1 | 110.8 | 172.2 | 288.4 |
| 20-24 | 67.9 | 104.9 | 172.9 | 77.5 | 89.6 | 160.2 | 305.4 |
| *DHS 3, 1998* | | | | | | | |
| 00-04 | 40.8 | 64.6 | 105.3 | 48.0 | 83.2 | 127.1 | 219.1 |
| 05-09 | 46.6 | 65.4 | 112.1 | 53.3 | 83.0 | 132.0 | 229.2 |
| 10-14 | 51.2 | 58.0 | 109.2 | 52.1 | 72.7 | 121.0 | 217.0 |
| 15-19 | 63.0 | 65.8 | 128.8 | 47.2 | 91.0 | 133.9 | 245.4 |
| 20-24 | 74.5 | 66.3 | 140.8 | 61.1 | 138.9 | 191.6 | 305.4 |

**Niger**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 2, 1992* | | | | | | | |
| 00-04 | 40.8 | 82.2 | 123.0 | 87.6 | 147.6 | 222.3 | 317.9 |
| 05-09 | 62.7 | 83.1 | 145.8 | 83.8 | 148.9 | 220.2 | 333.9 |
| 10-14 | 51.6 | 76.7 | 128.3 | 76.6 | 139.6 | 205.5 | 307.4 |
| 15-19 | 62.8 | 87.4 | 150.2 | 75.9 | 152.7 | 216.9 | 334.6 |
| 20-24 | 55.6 | 84.1 | 139.7 | 75.4 | 143.0 | 207.6 | 318.3 |
| *DHS 3, 1998* | | | | | | | |
| 00-04 | 44.2 | 78.8 | 123.1 | 70.5 | 108.9 | 171.7 | 273.7 |
| 05-09 | 57.4 | 92.0 | 149.4 | 82.9 | 147.5 | 218.2 | 335.0 |
| 10-14 | 51.7 | 85.3 | 137.0 | 78.0 | 146.8 | 213.3 | 321.1 |
| 15-19 | 56.8 | 78.1 | 134.9 | 70.7 | 150.1 | 210.1 | 316.7 |
| 20-24 | 70.8 | 89.5 | 160.3 | 78.6 | 159.1 | 225.2 | 349.4 |

**Guinea**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 4, 1999* | | | | | | | |
| 00-04 | 48.4 | 49.6 | 98.0 | 34.8 | 54.6 | 87.5 | 176.9 |
| 05-09 | 54.7 | 60.2 | 114.9 | 41.1 | 74.8 | 112.8 | 214.8 |
| 10-14 | 65.4 | 63.8 | 129.2 | 46.8 | 83.8 | 126.7 | 239.5 |
| 15-19 | 75.5 | 72.8 | 148.2 | 47.3 | 94.2 | 137.1 | 265.0 |
| 20-24 | 56.3 | 99.1 | 155.4 | 50.8 | 118.6 | 163.4 | 293.5 |

**Liberia**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 1, 1986* | | | | | | | |
| 00-04 | 67.2 | 75.2 | 142.4 | 48.6 | 44.1 | 90.6 | 220.1 |
| 05-09 | 73.1 | 87.4 | 160.5 | 45.7 | 49.6 | 93.0 | 238.6 |
| 10-14 | 82.7 | 102.8 | 185.6 | 44.8 | 56.5 | 98.7 | 266.0 |
| 15-19 | 95.4 | 120.5 | 215.9 | 51.0 | 55.2 | 103.3 | 296.9 |
| 20-24 | 117.1 | 112.1 | 229.2 | 53.4 | 65.0 | 114.9 | 317.7 |

**Côte d'Ivoire**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 3, 1994* | | | | | | | |
| 00-04 | 42.0 | 46.5 | 88.5 | 27.1 | 41.0 | 66.9 | 149.5 |
| 05-09 | 52.9 | 40.6 | 93.4 | 21.3 | 41.6 | 62.0 | 149.6 |
| 10-14 | 55.7 | 49.1 | 104.8 | 21.4 | 36.8 | 57.4 | 156.2 |
| 15-19 | 54.6 | 58.2 | 112.8 | 29.6 | 48.6 | 76.7 | 180.9 |
| 20-24 | 68.9 | 62.7 | 131.6 | 34.7 | 53.5 | 86.3 | 206.6 |

**Ghana**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 1, 1988* | | | | | | | |
| 00-04 | 43.3 | 33.7 | 77.0 | 29.7 | 56.0 | 84.0 | 154.5 |
| 05-09 | 51.5 | 33.8 | 85.3 | 25.5 | 49.3 | 73.5 | 152.5 |
| 10-14 | 61.5 | 37.1 | 98.5 | 34.5 | 61.1 | 93.5 | 182.8 |
| 15-19 | 57.0 | 48.7 | 105.7 | 32.5 | 62.3 | 92.7 | 188.6 |
| 20-24 | 57.2 | 29.5 | 86.7 | 32.4 | 63.9 | 94.2 | 172.7 |
| *DHS 2, 1993* | | | | | | | |
| 00-04 | 40.6 | 25.6 | 66.2 | 20.9 | 36.6 | 56.8 | 119.2 |
| 05-09 | 51.6 | 32.0 | 83.5 | 22.8 | 48.2 | 69.9 | 147.6 |
| 10-14 | 46.9 | 29.2 | 76.1 | 23.5 | 61.4 | 83.4 | 153.2 |
| 15-19 | 42.9 | 39.3 | 82.2 | 28.8 | 54.1 | 81.3 | 156.8 |
| 20-24 | 49.9 | 38.9 | 88.8 | 27.8 | 44.1 | 70.7 | 153.3 |
| *DHS 4, 1998* | | | | | | | |
| 00-04 | 29.7 | 27.1 | 56.7 | 19.5 | 34.4 | 53.2 | 106.9 |
| 05-09 | 35.1 | 30.0 | 65.1 | 18.2 | 33.2 | 50.8 | 112.6 |
| 10-14 | 40.7 | 33.1 | 73.8 | 21.5 | 56.2 | 76.6 | 144.7 |
| 15-19 | 39.8 | 36.1 | 75.8 | 25.3 | 39.5 | 63.8 | 134.9 |
| 20-24 | 35.9 | 35.8 | 71.7 | 29.6 | 53.6 | 81.6 | 147.5 |

**Togo**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 1, 1988* | | | | | | | |
| 00-04 | 39.7 | 37.6 | 77.3 | 27.7 | 57.3 | 83.4 | 154.3 |
| 05-09 | 51.3 | 40.0 | 91.3 | 27.3 | 55.5 | 81.3 | 165.2 |
| 10-14 | 50.3 | 51.0 | 101.2 | 34.7 | 75.1 | 107.3 | 197.6 |
| 15-19 | 52.4 | 48.1 | 100.4 | 39.5 | 89.6 | 125.5 | 213.4 |
| 20-24 | 53.8 | 57.9 | 111.8 | 42.9 | 117.9 | 155.7 | 250.1 |
| *DHS 3, 1998* | | | | | | | |
| 00-04 | 41.1 | 38.2 | 79.3 | 22.6 | 50.8 | 72.3 | 145.8 |
| 05-09 | 43.0 | 37.6 | 80.6 | 18.6 | 47.0 | 64.7 | 140.1 |
| 10-14 | 48.9 | 40.5 | 89.4 | 21.5 | 53.3 | 73.7 | 156.5 |
| 15-19 | 46.6 | 49.5 | 96.2 | 24.8 | 77.2 | 100.2 | 186.7 |
| 20-24 | 55.0 | 47.7 | 102.7 | 26.1 | 60.7 | 85.2 | 179.1 |

**Benin**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 3, 1996* | | | | | | | |
| 00-04 | 38.2 | 55.8 | 93.9 | 31.3 | 50.2 | 79.9 | 166.3 |
| 05-09 | 51.1 | 62.1 | 113.2 | 33.3 | 70.1 | 101.1 | 202.8 |
| 10-14 | 49.3 | 63.7 | 112.9 | 34.4 | 79.0 | 110.8 | 211.2 |
| 15-19 | 52.0 | 64.6 | 116.6 | 41.1 | 81.3 | 119.0 | 221.7 |
| 20-24 | 61.0 | 74.3 | 135.3 | 50.2 | 98.6 | 143.8 | 259.6 |

**Nigeria**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 2, 1990* | | | | | | | |
| 00-04 | 42.2 | 45.2 | 87.4 | 42.6 | 76.1 | 115.5 | 192.8 |
| 05-09 | 48.9 | 47.0 | 95.9 | 38.0 | 68.0 | 103.3 | 189.3 |
| 10-14 | 52.4 | 46.8 | 99.2 | 41.3 | 75.3 | 113.5 | 201.4 |
| 15-19 | 64.0 | 65.2 | 129.2 | 52.2 | 99.9 | 146.9 | 257.1 |
| 20-24 | 63.5 | 83.7 | 147.2 | 46.7 | 102.9 | 144.8 | 270.7 |
| *DHS 4, 1999* | | | | | | | |
| 00-04 | 36.9 | 38.3 | 75.2 | 28.2 | 43.4 | 70.3 | 140.2 |
| 05-09 | 33.0 | 33.1 | 66.2 | 24.6 | 40.3 | 63.9 | 125.8 |
| 10-14 | 35.8 | 41.3 | 77.0 | 26.3 | 45.7 | 70.8 | 142.3 |
| 15-19 | 38.7 | 34.9 | 73.7 | 25.7 | 42.8 | 67.4 | 136.1 |
| 20-24 | 43.3 | 56.9 | 100.2 | 20.0 | 38.3 | 57.6 | 152.0 |

**Cameroon**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 2, 1991* | | | | | | | |
| 00-04 | 32.8 | 31.5 | 64.3 | 29.8 | 36.5 | 65.2 | 125.3 |
| 05-09 | 52.4 | 45.3 | 97.7 | 28.9 | 46.4 | 73.9 | 164.3 |
| 10-14 | 55.4 | 52.7 | 108.1 | 41.5 | 61.0 | 100.0 | 197.3 |
| 15-19 | 56.8 | 55.2 | 112.1 | 30.8 | 68.2 | 96.9 | 198.1 |
| 20-24 | 84.6 | 47.7 | 132.3 | 46.2 | 85.6 | 127.8 | 243.2 |
| *DHS 3, 1998* | | | | | | | |
| 00-04 | 37.2 | 39.8 | 77.0 | 31.9 | 49.6 | 79.9 | 150.7 |
| 05-09 | 44.6 | 37.9 | 82.5 | 20.0 | 44.5 | 63.6 | 140.9 |
| 10-14 | 43.3 | 35.0 | 78.2 | 27.6 | 42.2 | 68.7 | 141.5 |
| 15-19 | 53.2 | 49.4 | 102.6 | 25.9 | 46.7 | 71.4 | 166.7 |
| 20-24 | 55.3 | 51.3 | 106.6 | 31.0 | 37.5 | 67.3 | 166.8 |

**Central African Republic**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 3, 1994* | | | | | | | |
| 00-04 | 42.1 | 54.6 | 96.7 | 26.0 | 42.4 | 67.3 | 157.5 |
| 05-09 | 48.5 | 58.6 | 107.0 | 21.7 | 36.7 | 57.6 | 158.4 |
| 10-14 | 47.6 | 54.8 | 102.3 | 22.2 | 45.7 | 66.9 | 162.4 |
| 15-19 | 48.5 | 62.3 | 110.7 | 26.6 | 47.8 | 73.1 | 175.7 |
| 20-24 | 46.3 | 64.6 | 110.9 | 29.6 | 47.1 | 75.3 | 177.8 |

**Chad**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 3, 1996* | | | | | | | |
| 00-04 | 43.9 | 58.5 | 102.4 | 41.8 | 62.9 | 102.0 | 194.0 |
| 05-09 | 51.1 | 66.2 | 117.3 | 36.2 | 69.8 | 103.4 | 208.6 |
| 10-14 | 59.3 | 58.4 | 117.8 | 40.6 | 75.4 | 113.0 | 217.4 |
| 15-19 | 59.3 | 64.4 | 123.7 | 49.2 | 82.1 | 127.3 | 235.3 |
| 20-24 | 59.8 | 66.8 | 126.6 | 45.4 | 76.1 | 118.0 | 229.7 |

**Kenya**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 1, 1989* | | | | | | | |
| 00-04 | 27.1 | 32.8 | 59.9 | 14.0 | 16.7 | 30.5 | 88.5 |
| 05-09 | 22.2 | 33.8 | 56.0 | 15.7 | 22.3 | 37.7 | 91.6 |
| 10-14 | 23.7 | 39.5 | 63.2 | 16.3 | 27.8 | 43.7 | 104.1 |
| 15-19 | 31.1 | 36.8 | 67.9 | 17.9 | 39.0 | 56.3 | 120.4 |
| 20-24 | 23.3 | 47.7 | 71.0 | 17.5 | 47.5 | 64.1 | 130.6 |
| *DHS 2, 1993* | | | | | | | |
| 00-04 | 25.7 | 35.9 | 61.7 | 15.3 | 21.7 | 36.6 | 96.0 |
| 05-09 | 28.1 | 35.2 | 63.3 | 12.4 | 15.9 | 28.1 | 89.5 |
| 10-14 | 34.3 | 34.3 | 68.6 | 15.8 | 19.8 | 35.3 | 101.4 |
| 15-19 | 33.4 | 37.7 | 71.1 | 22.3 | 35.2 | 56.7 | 123.8 |
| 20-24 | 45.7 | 54.0 | 99.7 | 18.3 | 40.4 | 57.9 | 151.9 |
| *DHS 3, 1998* | | | | | | | |
| 00-04 | 28.4 | 45.3 | 73.7 | 19.9 | 21.3 | 40.8 | 111.5 |
| 05-09 | 25.3 | 42.2 | 67.4 | 14.2 | 19.2 | 33.1 | 98.3 |
| 10-14 | 28.1 | 33.1 | 61.2 | 12.4 | 17.2 | 29.4 | 88.8 |
| 15-19 | 28.8 | 37.1 | 65.9 | 12.0 | 24.0 | 35.7 | 99.2 |
| 20-24 | 34.3 | 49.6 | 83.9 | 23.4 | 27.0 | 49.7 | 129.5 |

**Uganda**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 1, 1988* | | | | | | | |
| 00-04 | 42.5 | 55.0 | 97.5 | 38.4 | 50.7 | 87.1 | 176.1 |
| 05-09 | 56.0 | 59.3 | 115.3 | 37.2 | 60.1 | 95.0 | 199.4 |
| 10-14 | 46.9 | 49.3 | 96.2 | 33.8 | 67.9 | 99.4 | 186.1 |
| 15-19 | 42.8 | 44.2 | 87.0 | 25.3 | 52.4 | 76.3 | 156.7 |
| 20-24 | 68.0 | 57.2 | 125.2 | 27.0 | 59.8 | 85.2 | 199.7 |
| *DHS 3, 1995* | | | | | | | |
| 00-04 | 27.0 | 54.3 | 81.3 | 32.6 | 40.8 | 72.0 | 147.4 |
| 05-09 | 37.7 | 54.0 | 91.7 | 37.0 | 47.4 | 82.7 | 166.8 |
| 10-14 | 43.1 | 53.3 | 96.4 | 35.5 | 53.8 | 87.4 | 175.4 |
| 15-19 | 44.6 | 62.2 | 106.8 | 33.8 | 62.5 | 94.2 | 190.9 |
| 20-24 | 44.3 | 52.1 | 96.5 | 25.2 | 62.3 | 85.9 | 174.1 |

**Tanzania**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 2, 1992* | | | | | | | |
| 00-04 | 37.9 | 53.4 | 91.3 | 20.4 | 34.6 | 54.3 | 140.7 |
| 05-09 | 42.5 | 66.0 | 108.5 | 27.6 | 40.5 | 66.9 | 168.1 |
| 10-14 | 40.9 | 52.6 | 93.5 | 32.5 | 45.0 | 76.1 | 162.5 |
| 15-19 | 36.3 | 58.5 | 94.8 | 36.8 | 73.7 | 107.8 | 192.4 |
| 20-24 | 57.7 | 71.3 | 129.0 | 32.7 | 69.9 | 100.4 | 216.4 |
| *DHS 3, 1996* | | | | | | | |
| 00-04 | 31.7 | 55.6 | 87.3 | 23.3 | 31.1 | 53.6 | 136.3 |
| 05-09 | 41.5 | 59.8 | 101.3 | 25.5 | 33.5 | 58.2 | 153.6 |
| 10-14 | 46.5 | 54.7 | 101.3 | 30.2 | 41.9 | 70.8 | 164.9 |
| 15-19 | 40.3 | 48.1 | 88.4 | 24.4 | 45.9 | 69.1 | 151.4 |
| 20-24 | 31.8 | 60.7 | 92.5 | 41.9 | 53.3 | 92.9 | 176.8 |
| *DHS 4, 1999* | | | | | | | |
| 00-04 | 40.4 | 58.7 | 99.1 | 25.2 | 28.2 | 52.7 | 146.6 |
| 05-09 | 50.6 | 67.0 | 117.6 | 28.7 | 41.0 | 68.5 | 178.0 |
| 10-14 | 31.4 | 78.9 | 110.2 | 27.4 | 41.5 | 67.8 | 170.5 |
| 15-19 | 43.2 | 65.3 | 108.4 | 36.4 | 47.1 | 81.8 | 181.3 |
| 20-24 | 38.6 | 57.2 | 95.9 | 31.9 | 82.5 | 111.7 | 196.9 |

**Rwanda**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 2, 1992* | | | | | | | |
| 00-04 | 38.6 | 46.3 | 85.0 | 22.6 | 50.6 | 72.0 | 150.8 |
| 05-09 | 55.4 | 40.1 | 95.4 | 29.6 | 60.6 | 88.5 | 175.5 |
| 10-14 | 59.9 | 50.1 | 110.0 | 37.8 | 95.0 | 129.2 | 225.0 |
| 15-19 | 54.5 | 56.0 | 110.5 | 47.4 | 105.6 | 148.0 | 242.1 |
| 20-24 | 63.0 | 51.6 | 114.6 | 30.3 | 104.8 | 131.9 | 231.4 |

**Burundi**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 1, 1987* | | | | | | | |
| 00-04 | 35.2 | 38.5 | 73.7 | 27.7 | 59.0 | 85.1 | 152.5 |
| 05-09 | 42.3 | 57.5 | 99.8 | 43.3 | 98.1 | 137.1 | 223.3 |
| 10-14 | 43.9 | 60.4 | 104.4 | 45.0 | 103.1 | 143.5 | 232.9 |
| 15-19 | 51.3 | 47.9 | 99.2 | 33.8 | 110.3 | 140.4 | 225.7 |
| 20-24 | 41.7 | 56.6 | 98.3 | 27.0 | 104.6 | 128.8 | 214.5 |

**Ethiopia**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 4, 2000* | | | | | | | |
| 00-04 | 48.7 | 48.3 | 97.0 | 28.5 | 49.5 | 76.7 | 166.2 |
| 05-09 | 68.3 | 61.5 | 129.8 | 30.8 | 64.9 | 93.7 | 211.4 |
| 10-14 | 63.4 | 69.7 | 133.0 | 33.0 | 65.5 | 96.3 | 216.5 |
| 15-19 | 70.0 | 71.1 | 141.1 | 34.4 | 74.1 | 106.0 | 232.1 |
| 20-24 | 61.8 | 74.4 | 136.2 | 41.5 | 83.2 | 121.2 | 240.9 |

**Malawi**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 2, 1992* | | | | | | | |
| 00-04 | 41.2 | 93.5 | 134.6 | 51.1 | 66.8 | 114.5 | 233.8 |
| 05-09 | 57.9 | 80.0 | 137.9 | 51.9 | 78.3 | 126.1 | 246.6 |
| 10-14 | 63.3 | 74.6 | 137.9 | 54.1 | 91.7 | 140.8 | 259.3 |
| 15-19 | 64.8 | 88.3 | 153.1 | 63.1 | 125.4 | 180.6 | 306.0 |
| 20-24 | 82.3 | 90.6 | 172.9 | 59.9 | 175.5 | 224.9 | 358.9 |

**Mozambique**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 3, 1997* | | | | | | | |
| 00-04 | 53.5 | 79.3 | 132.8 | 20.1 | 56.4 | 75.4 | 198.2 |
| 05-09 | 59.4 | 101.0 | 160.4 | 35.2 | 56.8 | 90.1 | 236.0 |
| 10-14 | 54.6 | 78.2 | 132.8 | 34.0 | 45.5 | 78.0 | 200.4 |
| 15-19 | 46.4 | 86.5 | 132.9 | 25.0 | 47.7 | 71.5 | 194.9 |
| 20-24 | 86.5 | 76.1 | 162.6 | 35.7 | 69.2 | 102.5 | 248.5 |

**Namibia**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 2, 1992* | | | | | | | |
| 00-04 | 30.9 | 24.9 | 55.8 | 11.8 | 16.8 | 28.4 | 82.7 |
| 05-09 | 39.6 | 27.1 | 66.6 | 17.4 | 19.3 | 36.4 | 100.6 |
| 10-14 | 29.2 | 43.1 | 72.2 | 23.3 | 18.1 | 41.0 | 110.3 |
| 15-19 | 34.6 | 30.8 | 65.5 | 13.8 | 23.5 | 37.0 | 100.0 |
| 20-24 | 26.6 | 39.1 | 65.8 | 17.8 | 26.4 | 43.7 | 106.6 |

**Zambia**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 2, 1992* | | | | | | | |
| 00-04 | 42.5 | 64.7 | 107.2 | 52.7 | 43.6 | 94.0 | 191.1 |
| 05-09 | 37.1 | 50.5 | 87.6 | 42.4 | 40.9 | 81.6 | 162.1 |
| 10-14 | 31.3 | 47.9 | 79.2 | 32.0 | 48.0 | 78.4 | 151.5 |
| 15-19 | 29.2 | 39.0 | 68.2 | 35.7 | 48.7 | 82.7 | 145.2 |
| 20-24 | 37.0 | 64.1 | 101.1 | 39.9 | 58.7 | 96.3 | 187.7 |
| *DHS 3, 1996* | | | | | | | |
| 00-04 | 35.2 | 73.5 | 108.7 | 50.6 | 50.2 | 98.2 | 196.2 |
| 05-09 | 37.0 | 69.0 | 106.0 | 45.3 | 46.6 | 89.8 | 186.3 |
| 10-14 | 36.9 | 55.4 | 92.2 | 39.2 | 52.8 | 89.9 | 173.8 |
| 15-19 | 38.9 | 54.7 | 93.6 | 32.6 | 46.5 | 77.6 | 164.0 |
| 20-24 | 32.6 | 49.3 | 81.8 | 42.8 | 49.0 | 89.7 | 164.2 |

**Zimbabwe**

| Period before Survey | *NNM* | *PNNM* | $_1q_0$ | $_1q_1$ | $_3q_2$ | $_4q_1$ | $_5q_0$ |
|---|---|---|---|---|---|---|---|
| *DHS 1, 1988* | | | | | | | |
| 00-04 | 26.6 | 22.4 | 49.1 | 13.0 | 9.7 | 22.5 | 70.5 |
| 05-09 | 33.9 | 30.2 | 64.2 | 17.9 | 21.1 | 38.6 | 100.3 |
| 10-14 | 30.7 | 24.0 | 54.7 | 19.3 | 20.1 | 39.0 | 91.6 |
| 15-19 | 37.1 | 30.5 | 67.6 | 22.7 | 26.7 | 48.8 | 113.1 |
| 20-24 | 24.4 | 35.1 | 59.5 | 28.6 | 35.8 | 63.4 | 119.2 |
| *DHS 3, 1994* | | | | | | | |
| 00-04 | 24.1 | 28.4 | 52.5 | 14.5 | 11.3 | 25.6 | 76.8 |
| 05-09 | 25.5 | 24.1 | 49.6 | 13.0 | 13.5 | 26.4 | 74.7 |
| 10-14 | 24.9 | 33.5 | 58.5 | 21.3 | 23.6 | 44.4 | 100.3 |
| 15-19 | 32.5 | 30.3 | 62.8 | 22.3 | 27.8 | 49.5 | 109.2 |
| 20-24 | 21.1 | 28.6 | 49.7 | 23.4 | 23.2 | 46.0 | 93.4 |
| *DHS 4, 1999* | | | | | | | |
| 00-04 | 28.9 | 36.2 | 65.0 | 18.7 | 21.3 | 39.6 | 102.1 |
| 05-09 | 23.3 | 30.6 | 53.8 | 13.2 | 11.3 | 24.4 | 76.9 |
| 10-14 | 19.3 | 20.5 | 39.8 | 6.9 | 13.2 | 20.0 | 59.0 |
| 15-19 | 25.7 | 25.1 | 50.8 | 14.1 | 18.8 | 32.6 | 81.7 |
| 20-24 | 29.8 | 27.8 | 57.6 | 22.9 | 31.9 | 54.1 | 108.6 |

**South Africa**

| Period before Survey | *NNM* | *PNNM* | $_{1}q_{0}$ | $_{1}q_{1}$ | $_{3}q_{2}$ | $_{4}q_{1}$ | $_{5}q_{0}$ |
|---|---|---|---|---|---|---|---|
| *DHS 3, 1998* | | | | | | | |
| 00-04 | 19.8 | 25.6 | 45.4 | 8.5 | 6.3 | 14.7 | 59.4 |
| 05-09 | 18.6 | 20.6 | 39.2 | 8.1 | 8.2 | 16.2 | 54.8 |
| 10-14 | 22.6 | 28.1 | 50.7 | 11.9 | 8.6 | 20.4 | 70.1 |
| 15-19 | 25.2 | 37.7 | 62.9 | 14.6 | 11.7 | 26.1 | 87.4 |
| 20-24 | 26.6 | 55.9 | 82.5 | 23.5 | 23.9 | 46.8 | 125.4 |

# Appendix 3

# Indirect Estimates of ${}_5q_0$ Using DHS and Census Information on Proportions Dead of Children Ever Born

## SAHEL WEST AFRICA

### Senegal

| | Proportions Dead of CEB | q(x) | alpha | date | q(5) | Proportions Dead of CEB | q(x) | alpha | date | q(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **DHS 1, 1986** | | | | | **DHS 2, 1992/93** | | | | |
| **15-19** | 0.1529 | 0.1438 | 0.2350 | 1985.53 | 0.2348 | 0.1082 | 0.1055 | 0.0583 | 1991.97 | 0.1773 |
| **20-24** | 0.1706 | 0.1635 | 0.1711 | 1984.22 | 0.2127 | 0.1309 | 0.1281 | 0.0282 | 1990.70 | 0.1687 |
| **25-29** | 0.2007 | 0.1878 | 0.1812 | 1982.39 | 0.2160 | 0.1396 | 0.1323 | -0.0271 | 1988.93 | 0.1538 |
| **30-34** | 0.2152 | 0.2109 | 0.1659 | 1980.27 | 0.2109 | 0.1661 | 0.1641 | 0.0115 | 1986.84 | 0.1641 |
| **35-39** | 0.2688 | 0.2813 | 0.2646 | 1977.91 | 0.2456 | 0.1952 | 0.2055 | 0.0575 | 1984.51 | 0.1771 |
| **40-44** | 0.2808 | 0.2903 | 0.2403 | 1975.36 | 0.2367 | 0.2364 | 0.2457 | 0.1263 | 1981.97 | 0.1980 |
| **45-49** | 0.2975 | 0.3017 | 0.2196 | 1972.53 | 0.2293 | 0.2727 | 0.2779 | 0.1617 | 1979.12 | 0.2095 |
| | *P1/P2 = 0.2057; P2/P3 = 0.5073; Survey Date = 1986.75* | | | | | *P1/P2 = 0.1870; P2/P3 = 0.4833; Survey Date = 1993.13* | | | | |
| | **DHS 3, 1997** | | | | | | | | | |
| **15-19** | 0.1237 | 0.1148 | 0.1057 | 1995.97 | 0.1916 | | | | | |
| **20-24** | 0.1232 | 0.1205 | -0.0066 | 1994.76 | 0.1592 | | | | | |
| **25-29** | 0.1455 | 0.1396 | 0.0042 | 1993.11 | 0.1621 | | | | | |
| **30-34** | 0.1512 | 0.1519 | -0.0344 | 1991.18 | 0.1519 | | | | | |
| **35-39** | 0.1858 | 0.1989 | 0.0371 | 1989.04 | 0.1712 | | | | | |
| **40-44** | 0.2163 | 0.2284 | 0.0786 | 1986.64 | 0.1833 | | | | | |
| **45-49** | 0.2493 | 0.2575 | 0.1097 | 1983.83 | 0.1928 | | | | | |
| | *P1/P2 = 0.1962; P2/P3 = 0.4593; Survey date =1997.23* | | | | | | | | | |

### Mali

| | Proportions Dead of CEB | q(x) | alpha | date | q(5) | Proportions Dead of CEB | q(x) | alpha | date | q(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Census, 1987** | | | | | **DHS 1, 1987** | | | | |
| **15-19** | 0.2167 | 0.1870 | 0.3921 | 1985.99 | 0.2959 | 0.2100 | 0.1420 | 0.2275 | 1985.73 | 0.2321 |
| **20-24** | 0.2479 | 0.2272 | 0.3751 | 1984.57 | 0.2888 | 0.2421 | 0.2117 | 0.3298 | 1984.33 | 0.2706 |
| **25-29** | 0.2745 | 0.2502 | 0.3646 | 1982.65 | 0.2845 | 0.2215 | 0.2029 | 0.2292 | 1982.60 | 0.2328 |
| **30-34** | 0.3090 | 0.2980 | 0.3972 | 1980.45 | 0.2980 | 0.2707 | 0.2667 | 0.3200 | 1980.70 | 0.2667 |
| **35-39** | 0.3333 | 0.3448 | 0.4125 | 1978.05 | 0.3044 | 0.2902 | 0.3085 | 0.3300 | 1978.66 | 0.2707 |
| **40-44** | 0.3476 | 0.3560 | 0.3907 | 1975.49 | 0.2953 | 0.3194 | 0.3363 | 0.3472 | 1976.42 | 0.2775 |
| **45-49** | 0.3622 | 0.3643 | 0.3607 | 1972.68 | 0.2829 | 0.3701 | 0.3808 | 0.3962 | 1973.73 | 0.2976 |
| | *P1/P2 = 0.2469; P2/P3 = 0.5573; Census date = 1987.33* | | | | | *P1/P2 = 0.3096; P2/P3 = 0.5537; Survey date = 1987.43* | | | | |
| | **DHS 3, 1996** | | | | | | | | | |
| **15-19** | 0.2138 | 0.1894 | 0.3998 | 1994.80 | 0.2991 | | | | | |
| **20-24** | 0.2033 | 0.1905 | 0.2638 | 1993.45 | 0.2453 | | | | | |
| **25-29** | 0.2366 | 0.2194 | 0.2789 | 1991.62 | 0.2510 | | | | | |
| **30-34** | 0.2505 | 0.2448 | 0.2623 | 1989.51 | 0.2448 | | | | | |
| **35-39** | 0.2882 | 0.3015 | 0.3133 | 1987.19 | 0.2641 | | | | | |
| **40-44** | 0.3067 | 0.3172 | 0.3039 | 1984.68 | 0.2605 | | | | | |
| **45-49** | 0.3344 | 0.3392 | 0.3058 | 1981.87 | 0.2612 | | | | | |
| | *P1/P2 = 0.2299; P2/P3 = 0.5254; Survey date = 1996.12* | | | | | | | | | |

## Burkina Faso

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | DHS 2, 1992 | | | | | DHS 3, 1998 | | | | |
| **15-19** | 0.1608 | 0.1650 | 0.3162 | 1992.06 | 0.2653 | 0.1747 | 0.1909 | 0.4048 | 1998.14 | 0.3012 |
| **20-24** | 0.1719 | 0.1705 | 0.1961 | 1990.80 | 0.2211 | 0.1867 | 0.1873 | 0.2534 | 1996.86 | 0.2415 |
| **25-29** | 0.1844 | 0.1749 | 0.1377 | 1988.99 | 0.2017 | 0.2007 | 0.1892 | 0.1860 | 1994.95 | 0.2177 |
| **30-34** | 0.1986 | 0.1956 | 0.1186 | 1986.84 | 0.1956 | 0.2176 | 0.2118 | 0.1686 | 1992.67 | 0.2118 |
| **35-39** | 0.2122 | 0.2222 | 0.1072 | 1984.44 | 0.1920 | 0.2143 | 0.2215 | 0.1050 | 1990.10 | 0.1913 |
| **40-44** | 0.2486 | 0.2570 | 0.1563 | 1981.82 | 0.2077 | 0.2602 | 0.2654 | 0.1782 | 1987.35 | 0.2150 |
| **45-49** | 0.2796 | 0.2836 | 0.1759 | 1978.95 | 0.2142 | 0.3007 | 0.3017 | 0.2194 | 1984.43 | 0.2293 |
| | *P1/P2 = 0.1684; P2/P3 = 0.4792; Survey date = 1993.13* | | | | | *P1/P2 = 0.1485; P2/P3 = 0.4887; Survey date = 1999.08* | | | | |

## Niger

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | DHS 2, 1992 | | | | | DHS 3, 1998 | | | | |
| **15-19** | 0.1898 | 0.1885 | 0.3971 | 1991.27 | 0.2980 | 0.1713 | 0.1425 | 0.2296 | 1996.92 | 0.2329 |
| **20-24** | 0.2408 | 0.2305 | 0.3846 | 1989.89 | 0.2928 | 0.2357 | 0.2221 | 0.3605 | 1995.65 | 0.2829 |
| **25-29** | 0.2623 | 0.2414 | 0.3411 | 1987.92 | 0.2751 | 0.2594 | 0.2457 | 0.3526 | 1994.00 | 0.2797 |
| **30-34** | 0.2781 | 0.2673 | 0.3213 | 1985.61 | 0.2673 | 0.2788 | 0.2790 | 0.3510 | 1992.11 | 0.2790 |
| **35-39** | 0.3069 | 0.3148 | 0.3447 | 1983.05 | 0.2765 | 0.3180 | 0.3408 | 0.4037 | 1990.04 | 0.3007 |
| **40-44** | 0.3025 | 0.3068 | 0.2797 | 1980.32 | 0.2513 | 0.3135 | 0.3317 | 0.3370 | 1987.73 | 0.2735 |
| **45-49** | 0.3721 | 0.3712 | 0.3757 | 1977.45 | 0.2891 | 0.3332 | 0.3447 | 0.3179 | 1984.96 | 0.2659 |
| | *P1/P2 = 0.1961; P2/P3 = 0.5357; Survey date = 1992.38* | | | | | *P1/P2 = 0.2372; P2/P3 = 0.4874; Survey date = 1998.35* | | | | |

## COASTAL WEST AFRICA

### Guinea

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|
| | **DHS 4, 1999** | | | | |
| **15-19** | 0.1588 | 0.1289 | 0.1714 | 1998.05 | 0.2128 |
| **20-24** | 0.1548 | 0.1427 | 0.0909 | 1996.72 | 0.1870 |
| **25-29** | 0.1799 | 0.1675 | 0.1116 | 1994.97 | 0.1934 |
| **30-34** | 0.2210 | 0.2182 | 0.1877 | 1992.99 | 0.2182 |
| **35-39** | 0.2376 | 0.2516 | 0.1886 | 1990.83 | 0.2186 |
| **40-44** | 0.2664 | 0.2790 | 0.2125 | 1988.46 | 0.2268 |
| **45-49** | 0.2914 | 0.2987 | 0.2125 | 1985.70 | 0.2268 |
| | *P1/P2 =0.2536; P2/P3 = 0.5201; Survey date = 1999.51* | | | | |

### Liberia

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Census, 1974** | | | | | **DHS 1, 1986** | | | | |
| **15-19** | 0.1146 | 0.0788 | -0.1602 | 1972.41 | 0.1206 | 0.2054 | 0.1689 | 0.2721 | 1984.86 | 0.2456 |
| **20-24** | 0.1660 | 0.1491 | 0.0673 | 1970.72 | 0.1778 | 0.2165 | 0.2077 | 0.2687 | 1983.36 | 0.2444 |
| **25-29** | 0.2067 | 0.1939 | 0.1746 | 1968.59 | 0.2113 | 0.2435 | 0.2357 | 0.2987 | 1981.39 | 0.2556 |
| **30-34** | 0.2361 | 0.2310 | 0.2318 | 1966.29 | 0.2310 | 0.2418 | 0.2410 | 0.2596 | 1979.19 | 0.2410 |
| **35-39** | 0.2521 | 0.2540 | 0.2386 | 1963.92 | 0.2334 | 0.2671 | 0.2729 | 0.2873 | 1976.85 | 0.2513 |
| **40-44** | 0.2899 | 0.2894 | 0.2885 | 1961.43 | 0.2518 | 0.2837 | 0.2869 | 0.2825 | 1974.35 | 0.2495 |
| **45-49** | 0.3124 | 0.3092 | 0.2833 | 1958.71 | 0.2498 | 0.3170 | 0.3179 | 0.3036 | 1971.54 | 0.2575 |
| | *P1/P2 = 0.3502; P2/P3 = 0.6448; Census date = 1974.17* | | | | | *P1/P2 = 0.2771; P2/P3 = 0.5621; Survey date = 1986.38* | | | | |

### Côte d'Ivoire

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Census, 1988** | | | | | **DHS 3, 1994** | | | | |
| **15-19** | 0.1253 | 0.0914 | -0.0212 | 1986.66 | 0.1553 | 0.1416 | 0.1244 | 0.1513 | 1993.39 | 0.2061 |
| **20-24** | 0.1266 | 0.1105 | -0.0557 | 1985.19 | 0.1465 | 0.1494 | 0.1414 | 0.0855 | 1992.09 | 0.1854 |
| **25-29** | 0.1348 | 0.1213 | -0.0765 | 1983.31 | 0.1413 | 0.1430 | 0.1344 | -0.0180 | 1990.35 | 0.1561 |
| **30-34** | 0.1534 | 0.1481 | -0.0492 | 1981.21 | 0.1481 | 0.1510 | 0.1495 | -0.0438 | 1988.34 | 0.1495 |
| **35-39** | 0.1792 | 0.1866 | -0.0026 | 1978.96 | 0.1602 | 0.1689 | 0.1788 | -0.0286 | 1986.13 | 0.1534 |
| **40-44** | 0.2156 | 0.2225 | 0.0616 | 1976.53 | 0.1783 | 0.1901 | 0.1988 | -0.0097 | 1983.70 | 0.1583 |
| **45-49** | 0.2455 | 0.2483 | 0.0853 | 1973.80 | 0.1853 | 0.2176 | 0.2228 | 0.0145 | 1980.90 | 0.1649 |
| | *P1/P2 = 0.3003; P2/P3 = 0.5844; Census date = 1988.25* | | | | | *P1/P2 = 0.2252; P2/P3 = 0.5009; Survey date = 1994.73* | | | | |

## Ghana

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **DHS 1, 1988** | | | | | **DHS 2, 1993** | | | | |
| **15-19** | 0.0656 | 0.0662 | -0.1963 | 1987.23 | 0.1147 | 0.0655 | 0.0658 | -0.1998 | 1992.82 | 0.1140 |
| **20-24** | 0.1390 | 0.1378 | 0.0705 | 1985.98 | 0.1809 | 0.1151 | 0.1125 | -0.0455 | 1991.52 | 0.1490 |
| **25-29** | 0.1466 | 0.1396 | 0.0040 | 1984.21 | 0.1620 | 0.1274 | 0.1196 | -0.0846 | 1989.67 | 0.1394 |
| **30-34** | 0.1625 | 0.1608 | -0.0003 | 1982.11 | 0.1608 | 0.1331 | 0.1301 | -0.1242 | 1987.48 | 0.1301 |
| **35-39** | 0.1643 | 0.1729 | -0.0489 | 1979.77 | 0.1482 | 0.1469 | 0.1530 | -0.1222 | 1985.04 | 0.1306 |
| **40-44** | 0.1812 | 0.1883 | -0.0435 | 1977.20 | 0.1495 | 0.1533 | 0.1577 | -0.1505 | 1982.40 | 0.1243 |
| **45-49** | 0.2212 | 0.2253 | 0.0217 | 1974.33 | 0.1669 | 0.1942 | 0.1961 | -0.0663 | 1979.53 | 0.1438 |
| | *P1/P2 = 0.1721; P2/P3 = 0.4724; Survey date = 1988.33* | | | | | *P1/P2 = 0.1814; P2/P3 = 0.4984; Survey date = 1993.92* | | | | |
| | **DHS 4, 1998** | | | | | | | | | |
| **15-19** | 0.0926 | 0.1090 | 0.0763 | 1998.22 | 0.1826 | | | | | |
| **20-24** | 0.1112 | 0.1135 | -0.0404 | 1996.92 | 0.1503 | | | | | |
| **25-29** | 0.1033 | 0.0970 | -0.2021 | 1994.93 | 0.1135 | | | | | |
| **30-34** | 0.1327 | 0.1277 | -0.1353 | 1992.50 | 0.1277 | | | | | |
| **35-39** | 0.1363 | 0.1389 | -0.1786 | 1989.75 | 0.1183 | | | | | |
| **40-44** | 0.1625 | 0.1635 | -0.1291 | 1986.84 | 0.1290 | | | | | |
| **45-49** | 0.1753 | 0.1737 | -0.1405 | 1983.88 | 0.1265 | | | | | |
| | *P1/P2 = 0.1211; P2/P3 = 0.4933; Survey date = 1999.00* | | | | | | | | | |

## Togo

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **DHS 1, 1988** | | | | | **DHS 3, 1998** | | | | |
| **15-19** | 0.1064 | 0.1029 | 0.0440 | 1987.52 | 0.1732 | 0.1558 | 0.1523 | 0.2684 | 1997.10 | 0.2470 |
| **20-24** | 0.1198 | 0.1171 | -0.0226 | 1986.26 | 0.1549 | 0.1204 | 0.1218 | -0.0004 | 1995.99 | 0.1608 |
| **25-29** | 0.1453 | 0.1380 | -0.0026 | 1984.51 | 0.1602 | 0.1409 | 0.1384 | -0.0010 | 1994.45 | 0.1607 |
| **30-34** | 0.1821 | 0.1805 | 0.0690 | 1982.45 | 0.1805 | 0.1509 | 0.1541 | -0.0260 | 1992.62 | 0.1541 |
| **35-39** | 0.1874 | 0.1978 | 0.0336 | 1980.16 | 0.1702 | 0.1750 | 0.1898 | 0.0080 | 1990.56 | 0.1631 |
| **40-44** | 0.2230 | 0.2324 | 0.0898 | 1977.64 | 0.1867 | 0.1871 | 0.1999 | -0.0064 | 1988.22 | 0.1592 |
| **45-49** | 0.2329 | 0.2379 | 0.0570 | 1974.80 | 0.1769 | 0.2173 | 0.2268 | 0.0260 | 1985.38 | 0.1681 |
| | *P1/P2 = 0.1886; P2/P3 = 0.4790; Survey date = 1988.70* | | | | | *P1/P2 = 0.1660; P2/P3 = 0.4136; Survey date = 1998.29* | | | | |

**Benin**

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|
| | **DHS 3, 1996** | | | | |
| **15-19** | 0.1373 | 0.1378 | 0.2101 | 1995.56 | 0.2260 |
| **20-24** | 0.1377 | 0.1358 | 0.0619 | 1994.30 | 0.1784 |
| **25-29** | 0.1638 | 0.1553 | 0.0668 | 1992.51 | 0.1798 |
| **30-34** | 0.1940 | 0.1914 | 0.1052 | 1990.39 | 0.1914 |
| **35-39** | 0.2176 | 0.2284 | 0.1250 | 1988.02 | 0.1976 |
| **40-44** | 0.2581 | 0.2675 | 0.1836 | 1985.44 | 0.2168 |
| **45-49** | 0.2856 | 0.2903 | 0.1923 | 1982.58 | 0.2198 |
| | *P1/P2 = 0.1763; P2/P3 = 0.4802; Survey date = 1996.67* | | | | |

**Nigeria**

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **DHS 2, 1990** | | | | | **DHS 4, 1999** | | | | |
| **15-19** | 0.1526 | 0.1342 | 0.1947 | 1989.21 | 0.2207 | 0.1286 | 0.1065 | 0.0634 | 1997.92 | 0.1788 |
| **20-24** | 0.1618 | 0.1559 | 0.1426 | 1987.98 | 0.2033 | 0.1257 | 0.1207 | -0.0055 | 1996.74 | 0.1595 |
| **25-29** | 0.1725 | 0.1650 | 0.1029 | 1986.36 | 0.1907 | 0.1299 | 0.1256 | -0.0565 | 1995.22 | 0.1462 |
| **30-34** | 0.1821 | 0.1832 | 0.0782 | 1984.47 | 0.1832 | 0.1379 | 0.1407 | -0.0791 | 1993.49 | 0.1407 |
| **35-39** | 0.2120 | 0.2277 | 0.1229 | 1982.40 | 0.1970 | 0.1473 | 0.1607 | -0.0929 | 1991.59 | 0.1374 |
| **40-44** | 0.2297 | 0.2435 | 0.1204 | 1980.06 | 0.1962 | 0.1432 | 0.1540 | -0.1644 | 1989.40 | 0.1213 |
| **45-49** | 0.2633 | 0.2729 | 0.1492 | 1977.27 | 0.2054 | 0.1864 | 0.1956 | -0.0678 | 1986.64 | 0.1435 |
| | *P1/P2 = 0.2149; P2/P3 = 0.4668; Survey date = 1990.56* | | | | | *P1/P2 = 0.2267; P2/P3 = 0.4468; Survey date = 1999.37* | | | | |

**MIDDLE AFRICA**

## Cameroon

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **DHS 2, 1991** | | | | | **DHS 3, 1998** | | | | |
| **15-19** | 0.0855 | 0.0799 | -0.0950 | 1990.28 | 0.1369 | 0.1436 | 0.1146 | 0.1046 | 1996.79 | 0.1912 |
| **20-24** | 0.1308 | 0.1236 | 0.0078 | 1988.91 | 0.1631 | 0.1266 | 0.1207 | -0.0059 | 1995.61 | 0.1594 |
| **25-29** | 0.1271 | 0.1173 | -0.0957 | 1987.00 | 0.1367 | 0.1361 | 0.1316 | -0.0299 | 1994.12 | 0.1530 |
| **30-34** | 0.1471 | 0.1425 | -0.0719 | 1984.79 | 0.1425 | 0.1429 | 0.1461 | -0.0569 | 1992.43 | 0.1461 |
| **35-39** | 0.1704 | 0.1765 | -0.0368 | 1982.35 | 0.1513 | 0.1469 | 0.1608 | -0.0925 | 1990.57 | 0.1375 |
| **40-44** | 0.2011 | 0.2059 | 0.0124 | 1979.73 | 0.1643 | 0.1778 | 0.1920 | -0.0314 | 1988.43 | 0.1526 |
| **45-49** | 0.2553 | 0.2568 | 0.1079 | 1976.90 | 0.1922 | 0.1939 | 0.2041 | -0.0413 | 1985.69 | 0.1501 |
| | *P1/P2 = 0.2156; P2/P3 = 0.5331; Survey date = 1991.50* | | | | | *P1/P2 = 0.2375; P2/P3 = 0.4486; Survey date = 1998.30* | | | | |

## Central African Republic

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Census, 1975** | | | | | **DHS 3, 1994** | | | | |
| **15-19** | 0.2104 | 0.1355 | 0.2001 | 1974.23 | 0.2225 | 0.1578 | 0.1391 | 0.2157 | 1993.66 | 0.2280 |
| **20-24** | 0.2036 | 0.1684 | 0.1888 | 1972.65 | 0.2186 | 0.1396 | 0.1307 | 0.0400 | 1992.31 | 0.1720 |
| **25-29** | 0.2362 | 0.2064 | 0.2402 | 1970.66 | 0.2367 | 0.1594 | 0.1479 | 0.0380 | 1990.48 | 0.1715 |
| **30-34** | 0.2571 | 0.2439 | 0.2598 | 1968.49 | 0.2439 | 0.1570 | 0.1536 | -0.0278 | 1988.38 | 0.1536 |
| **35-39** | 0.3114 | 0.3203 | 0.3572 | 1966.19 | 0.2815 | 0.1692 | 0.1772 | -0.0342 | 1986.07 | 0.1519 |
| **40-44** | 0.3456 | 0.3531 | 0.3845 | 1963.76 | 0.2927 | 0.1905 | 0.1972 | -0.0146 | 1983.57 | 0.1570 |
| **45-49** | 0.3843 | 0.3853 | 0.4056 | 1961.07 | 0.3015 | 0.2312 | 0.2347 | 0.0483 | 1980.77 | 0.1744 |
| | *P1/P2 = 0.3452; P2/P3 = 0.6379; Census date = 1975.96* | | | | | *P1/P2 = 0.2308; P2/P3 = 0.5242; Survey date = 1994.98* | | | | |

## Chad

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|
| | **DHS, 1996** | | | | |
| **15-19** | 0.1532 | 0.1386 | 0.2135 | 1996.01 | 0.2272 |
| **20-24** | 0.1653 | 0.1570 | 0.1469 | 1994.70 | 0.2047 |
| **25-29** | 0.1789 | 0.1674 | 0.1114 | 1992.91 | 0.1933 |
| **30-34** | 0.2006 | 0.1973 | 0.1239 | 1990.83 | 0.1973 |
| **35-39** | 0.2271 | 0.2388 | 0.1539 | 1988.54 | 0.2069 |
| **40-44** | 0.2465 | 0.2561 | 0.1539 | 1986.04 | 0.2069 |
| **45-49** | 0.2924 | 0.2977 | 0.2100 | 1983.23 | 0.2260 |
| | *P1/P2 = 0.2182; P2/P3 = 0.5082; Survey date = 1997.30* | | | | |

# EASTERN AFRICA

## Kenya

**Census, 1962**

| | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ |
|---|---|---|---|---|---|
| **15-19** | 0.1460 | 0.1657 | 0.2607 | 1961.62 | 0.2415 |
| **20-24** | 0.1700 | 0.1746 | 0.1615 | 1960.15 | 0.2070 |
| **25-29** | 0.2050 | 0.1981 | 0.1878 | 1957.88 | 0.2157 |
| **30-34** | 0.2380 | 0.2320 | 0.2345 | 1955.17 | 0.2320 |
| **35-39** | 0.2690 | 0.2666 | 0.2713 | 1952.19 | 0.2454 |
| **40-44** | 0.3080 | 0.3013 | 0.3170 | 1949.17 | 0.2627 |
| **45-49** | 0.3380 | 0.3282 | 0.3272 | 1946.24 | 0.2666 |

*P1/P2 = 0.1576; P2/P3 = 0.5482; Census date = 1962.50*

**Census, 1969**

| | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ |
|---|---|---|---|---|---|
| **15-19** | 0.1280 | 0.1303 | 0.1197 | 1968.37 | 0.1936 |
| **20-24** | 0.1470 | 0.1496 | 0.0692 | 1966.98 | 0.1783 |
| **25-29** | 0.1740 | 0.1709 | 0.0973 | 1964.96 | 0.1867 |
| **30-34** | 0.2020 | 0.2014 | 0.1441 | 1962.59 | 0.2014 |
| **35-39** | 0.2310 | 0.2347 | 0.1865 | 1960.01 | 0.2153 |
| **40-44** | 0.2630 | 0.2642 | 0.2254 | 1957.29 | 0.2288 |
| **45-49** | 0.3040 | 0.3030 | 0.2687 | 1954.39 | 0.2444 |

*P1/P2 = 0.1915; P2/P3 = 0.5151; Census date = 1969.50*

**Census, 1979**

| | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ |
|---|---|---|---|---|---|
| **15-19** | 0.1160 | 0.1232 | 0.0874 | 1978.45 | 0.1837 |
| **20-24** | 0.1250 | 0.1287 | -0.0181 | 1977.08 | 0.1542 |
| **25-29** | 0.1410 | 0.1388 | -0.0257 | 1975.05 | 0.1522 |
| **30-34** | 0.1660 | 0.1653 | 0.0235 | 1972.64 | 0.1653 |
| **35-39** | 0.1850 | 0.1876 | 0.0445 | 1969.99 | 0.1712 |
| **40-44** | 0.2170 | 0.2174 | 0.0973 | 1967.21 | 0.1867 |
| **45-49** | 0.2530 | 0.2516 | 0.1402 | 1964.29 | 0.2001 |

*P1/P2 = 0.1730; P2/P3 = 0.5068; Census date = 1979.50*

**DHS 1, 1989**

| | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ |
|---|---|---|---|---|---|
| **15-19** | 0.1268 | 0.1245 | 0.0938 | 1988.02 | 0.1856 |
| **20-24** | 0.0909 | 0.0940 | -0.1944 | 1986.76 | 0.1135 |
| **25-29** | 0.0852 | 0.0858 | -0.2962 | 1985.01 | 0.0946 |
| **30-34** | 0.0984 | 0.1004 | -0.2631 | 1982.95 | 0.1004 |
| **35-39** | 0.1090 | 0.1135 | -0.2506 | 1980.69 | 0.1027 |
| **40-44** | 0.1274 | 0.1312 | -0.2074 | 1978.18 | 0.1110 |
| **45-49** | 0.1424 | 0.1455 | -0.1999 | 1975.26 | 0.1125 |

*P1/P2 = 0.1879; P2/P3 = 0.4562; Survey date = 1989.25*

**Census, 1989**

| | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ |
|---|---|---|---|---|---|
| **15-19** | 0.1110 | 0.1155 | 0.0512 | 1988.40 | 0.1731 |
| **20-24** | 0.1040 | 0.1078 | -0.1185 | 1987.09 | 0.1298 |
| **25-29** | 0.1080 | 0.1075 | -0.1711 | 1985.18 | 0.1183 |
| **30-34** | 0.1260 | 0.1269 | -0.1311 | 1982.92 | 0.1269 |
| **35-39** | 0.1390 | 0.1426 | -0.1195 | 1980.43 | 0.1295 |
| **40-44** | 0.1650 | 0.1673 | -0.0646 | 1977.75 | 0.1424 |
| **45-49** | 0.1860 | 0.1872 | -0.0489 | 1974.83 | 0.1463 |

*P1/P2 = 0.1731; P2/P3 = 0.4800; Census date = 1989.50*

**DHS 2, 1993**

| | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ |
|---|---|---|---|---|---|
| **15-19** | 0.1209 | 0.1294 | 0.1159 | 1992.32 | 0.1924 |
| **20-24** | 0.0862 | 0.0915 | -0.2095 | 1991.12 | 0.1105 |
| **25-29** | 0.0874 | 0.0886 | -0.2784 | 1989.34 | 0.0977 |
| **30-34** | 0.1040 | 0.1062 | -0.2318 | 1987.22 | 0.1062 |
| **35-39** | 0.1146 | 0.1190 | -0.2234 | 1984.85 | 0.1078 |
| **40-44** | 0.1269 | 0.1304 | -0.2111 | 1982.24 | 0.1102 |
| **45-49** | 0.1435 | 0.1462 | -0.1970 | 1979.28 | 0.1130 |

*P1/P2 = 0.1490; P2/P3 = 0.4341; Survey date = 1993.38*

**DHS 3, 1998**

| | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ |
|---|---|---|---|---|---|
| **15-19** | 0.1269 | 0.1316 | 0.1256 | 1997.23 | 0.1954 |
| **20-24** | 0.0952 | 0.0991 | -0.1652 | 1995.95 | 0.1196 |
| **25-29** | 0.0955 | 0.0956 | -0.2364 | 1994.09 | 0.1054 |
| **30-34** | 0.1076 | 0.1090 | -0.2173 | 1991.89 | 0.1090 |
| **35-39** | 0.0968 | 0.0999 | -0.3220 | 1989.47 | 0.0903 |
| **40-44** | 0.1282 | 0.1307 | -0.2095 | 1986.84 | 0.1105 |
| **45-49** | 0.1563 | 0.1581 | -0.1507 | 1983.91 | 0.1226 |

*P1/P2 = 0.1703; P2/P3 = 0.4660; Survey date = 1998.34*

## Uganda

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Census, 1969** | | | | | **DHS 1, 1988** | | | | |
| **15-19** | 0.1340 | 0.1227 | 0.1436 | 1967.76 | 0.2036 | 0.1478 | 0.1318 | 0.1845 | 1987.62 | 0.2172 |
| **20-24** | 0.1620 | 0.1483 | 0.1134 | 1966.28 | 0.1940 | 0.1755 | 0.1678 | 0.1867 | 1986.35 | 0.2179 |
| **25-29** | 0.1920 | 0.1721 | 0.1282 | 1964.22 | 0.1986 | 0.1693 | 0.1602 | 0.0851 | 1984.64 | 0.1853 |
| **30-34** | 0.2260 | 0.2137 | 0.1741 | 1961.84 | 0.2137 | 0.1794 | 0.1785 | 0.0622 | 1982.66 | 0.1785 |
| **35-39** | 0.2550 | 0.2585 | 0.2066 | 1959.22 | 0.2248 | 0.1802 | 0.1916 | 0.0136 | 1980.48 | 0.1646 |
| **40-44** | 0.3050 | 0.3064 | 0.2787 | 1956.49 | 0.2509 | 0.1953 | 0.2050 | 0.0095 | 1978.06 | 0.1635 |
| **45-49** | 0.3480 | 0.3442 | 0.3168 | 1953.65 | 0.2655 | 0.2181 | 0.2240 | 0.0180 | 1975.26 | 0.1659 |
| | *P1/P2 = 0.2370; P2/P3 = 0.5855; Census date = 1969.00* | | | | | *P1/P2 = 0.2168; P2/P3 = 0.4876; Survey date = 1988.94* | | | | |
| | **Census, 1991** | | | | | **DHS 3, 1995** | | | | |
| **15-19** | 0.1500 | 0.1424 | 0.2292 | 1989.80 | 0.2327 | 0.1362 | 0.1214 | 0.1375 | 1994.16 | 0.2016 |
| **20-24** | 0.1690 | 0.1611 | 0.1622 | 1988.45 | 0.2097 | 0.1376 | 0.1277 | 0.0265 | 1992.77 | 0.1682 |
| **25-29** | 0.1870 | 0.1735 | 0.1328 | 1986.57 | 0.2001 | 0.1423 | 0.1304 | -0.0351 | 1990.86 | 0.1517 |
| **30-34** | 0.2090 | 0.2031 | 0.1422 | 1984.37 | 0.2031 | 0.1620 | 0.1565 | -0.0166 | 1988.65 | 0.1565 |
| **35-39** | 0.2260 | 0.2346 | 0.1423 | 1981.94 | 0.2032 | 0.1687 | 0.1746 | -0.0431 | 1986.24 | 0.1496 |
| **40-44** | 0.2520 | 0.2586 | 0.1606 | 1979.33 | 0.2092 | 0.1956 | 0.2003 | -0.0049 | 1983.65 | 0.1596 |
| **45-49** | 0.2710 | 0.2731 | 0.1497 | 1976.49 | 0.2056 | 0.2030 | 0.2042 | -0.0411 | 1980.84 | 0.1501 |
| | *P1/P2 = 0.2074; P2/P3 = 0.5228; Census date = 1991.00* | | | | | *P1/P2 = 0.2340; P2/P3 = 0.5469; Survey date = 1995.46* | | | | |

## Tanzania

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **DHS 2, 1992** | | | | | **DHS 3, 1996** | | | | |
| **15-19** | 0.1165 | 0.1178 | 0.0623 | 1990.86 | 0.1763 | 0.1198 | 0.1227 | 0.0854 | 1995.59 | 0.1831 |
| **20-24** | 0.1305 | 0.1337 | 0.0040 | 1989.52 | 0.1600 | 0.1380 | 0.1427 | 0.0418 | 1994.29 | 0.1704 |
| **25-29** | 0.1495 | 0.1481 | 0.0123 | 1987.59 | 0.1623 | 0.1373 | 0.1369 | -0.0338 | 1992.41 | 0.1501 |
| **30-34** | 0.1600 | 0.1609 | 0.0071 | 1985.33 | 0.1609 | 0.1484 | 0.1499 | -0.0348 | 1990.19 | 0.1499 |
| **35-39** | 0.1773 | 0.1817 | 0.0248 | 1982.85 | 0.1657 | 0.1561 | 0.1606 | -0.0496 | 1987.75 | 0.1461 |
| **40-44** | 0.1812 | 0.1835 | -0.0086 | 1980.19 | 0.1566 | 0.1712 | 0.1742 | -0.0404 | 1985.11 | 0.1484 |
| **45-49** | 0.2180 | 0.2191 | 0.0498 | 1977.28 | 0.1727 | 0.2058 | 0.2077 | 0.0158 | 1982.19 | 0.1632 |
| | *P1/P2 = 0.1879; P2/P3 = 0.4938; Survey date = 1992.02* | | | | | *P1/P2 = 0.1783; P2/P3 = 0.4771; Survey date = 1996.73* | | | | |
| | **DHS 4, 1999** | | | | | | | | | |
| **15-19** | 0.1485 | 0.1613 | 0.2446 | 1998.82 | 0.2356 | | | | | |
| **20-24** | 0.1479 | 0.1537 | 0.0854 | 1997.47 | 0.1831 | | | | | |
| **25-29** | 0.1494 | 0.1477 | 0.0106 | 1995.45 | 0.1618 | | | | | |
| **30-34** | 0.1500 | 0.1497 | -0.0354 | 1993.04 | 0.1497 | | | | | |
| **35-39** | 0.1755 | 0.1782 | 0.0129 | 1990.39 | 0.1624 | | | | | |
| **40-44** | 0.1844 | 0.1849 | -0.0040 | 1987.59 | 0.1579 | | | | | |
| **45-49** | 0.1991 | 0.1982 | -0.0134 | 1984.66 | 0.1554 | | | | | |
| | *P1/P2 = 0.1608; P2/P3 = 0.4955; Survey date = 1999.82* | | | | | | | | | |

## Rwanda

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Census, 1978** | | | | | **Demographic Survey, 1981** | | | | |
| **15-19** | 0.1290 | 0.1504 | 0.2614 | 1977.81 | 0.2444 | 0.1529 | 0.1787 | 0.3642 | 1980.82 | 0.2844 |
| **20-24** | 0.1679 | 0.1810 | 0.2324 | 1976.80 | 0.2339 | 0.1589 | 0.1716 | 0.2001 | 1979.81 | 0.2225 |
| **25-29** | 0.2022 | 0.2029 | 0.2293 | 1975.24 | 0.2328 | 0.2043 | 0.2053 | 0.2368 | 1978.25 | 0.2355 |
| **30-34** | 0.2168 | 0.2220 | 0.1986 | 1973.30 | 0.2220 | 0.2148 | 0.2202 | 0.1935 | 1976.32 | 0.2202 |
| **35-39** | 0.2302 | 0.2485 | 0.1803 | 1971.07 | 0.2157 | 0.2451 | 0.2649 | 0.2232 | 1974.10 | 0.2306 |
| **40-44** | 0.2437 | 0.2587 | 0.1608 | 1968.55 | 0.2092 | 0.2584 | 0.2745 | 0.2011 | 1971.58 | 0.2229 |
| **45-49** | 0.2705 | 0.2810 | 0.1693 | 1965.62 | 0.2120 | 0.2691 | 0.2797 | 0.1662 | 1968.65 | 0.2110 |
| | *P1/P2 = 0.0878; P2/P3 = 0.3662; Census date = 1978.67* | | | | | *P1/P2 = 0.0862; P2/P3 = 0.3632; Census date = 1981.67* | | | | |
| | **DHS 2, 1992** | | | | | | | | | |
| **15-19** | 0.1056 | 0.1111 | 0.0873 | 1991.57 | 0.1859 | | | | | |
| **20-24** | 0.1360 | 0.1443 | 0.0971 | 1990.59 | 0.1889 | | | | | |
| **25-29** | 0.1544 | 0.1567 | 0.0718 | 1989.20 | 0.1813 | | | | | |
| **30-34** | 0.1723 | 0.1801 | 0.0677 | 1987.51 | 0.1801 | | | | | |
| **35-39** | 0.1863 | 0.2059 | 0.0586 | 1985.57 | 0.1774 | | | | | |
| **40-44** | 0.2308 | 0.2505 | 0.1393 | 1983.29 | 0.2022 | | | | | |
| **45-49** | 0.2472 | 0.2618 | 0.1208 | 1980.43 | 0.1963 | | | | | |
| | *P1/P2 = 0.1214; P2/P3 = 0.3474; Survey date = 1992.64* | | | | | | | | | |

## Burundi

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|
| | **DHS 1, 1987** | | | | |
| **15-19** | 0.1400 | 0.1681 | 0.3275 | 1986.64 | 0.2697 |
| **20-24** | 0.1320 | 0.1442 | 0.0968 | 1985.65 | 0.1888 |
| **25-29** | 0.1577 | 0.1592 | 0.0812 | 1984.10 | 0.1841 |
| **30-34** | 0.1732 | 0.1779 | 0.0602 | 1982.16 | 0.1779 |
| **35-39** | 0.1907 | 0.2061 | 0.0594 | 1979.92 | 0.1776 |
| **40-44** | 0.2312 | 0.2455 | 0.1258 | 1977.37 | 0.1979 |
| **45-49** | 0.2504 | 0.2602 | 0.1166 | 1974.42 | 0.1950 |
| | *P1/P2 = 0.0722; P2/P3 = 0.3531; Survey date = 1987.43* | | | | |

## Ethiopia

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|
| | **DHS 4, 2000** | | | | |
| **15-19** | 0.1445 | 0.1547 | 0.2779 | 1999.33 | 0.2506 |
| **20-24** | 0.1533 | 0.1568 | 0.1463 | 1998.16 | 0.2045 |
| **25-29** | 0.1808 | 0.1753 | 0.1392 | 1996.46 | 0.2021 |
| **30-34** | 0.2009 | 0.2011 | 0.1358 | 1994.40 | 0.2011 |
| **35-39** | 0.2255 | 0.2393 | 0.1553 | 1992.08 | 0.2074 |
| **40-44** | 0.2578 | 0.2696 | 0.1889 | 1989.52 | 0.2187 |
| **45-49** | 0.2896 | 0.2968 | 0.2078 | 1986.63 | 0.2252 |
| | *P1/P2 = 0.1407; P2/P3 = 0.4358; Survey date = 2000.33* | | | | |

## SOUTHERN AFRICA

### Zambia

| | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Census, 1969** | | | | | **Census, 1990** | | | | |
| **15-19** | 0.1459 | 0.1562 | 0.2837 | 1968.71 | 0.2528 | 0.1364 | 0.1388 | 0.2143 | 1989.57 | 0.2275 |
| **20-24** | 0.1678 | 0.1614 | 0.1634 | 1967.27 | 0.2101 | 0.1574 | 0.1582 | 0.1514 | 1988.38 | 0.2061 |
| **25-29** | 0.1911 | 0.1729 | 0.1309 | 1965.13 | 0.1995 | 0.1626 | 0.1570 | 0.0730 | 1986.69 | 0.1816 |
| **30-34** | 0.2155 | 0.2024 | 0.1399 | 1962.59 | 0.2024 | 0.1616 | 0.1618 | 0.0032 | 1984.68 | 0.1618 |
| **35-39** | 0.2473 | 0.2475 | 0.1776 | 1959.77 | 0.2148 | 0.1667 | 0.1773 | -0.0338 | 1982.42 | 0.1520 |
| **40-44** | 0.2865 | 0.2839 | 0.2246 | 1956.83 | 0.2311 | 0.1998 | 0.2095 | 0.0233 | 1979.91 | 0.1673 |
| **45-49** | 0.3111 | 0.3042 | 0.2255 | 1953.91 | 0.2314 | 0.2233 | 0.2294 | 0.0333 | 1977.05 | 0.1701 |
| | *P1/P2 = 0.1781; P2/P3 = 0.5650; Census date = 1969.67* | | | | | *P1/P2 = 0.1619; P2/P3 = 0.4464; Census date = 1990.67* | | | | |
| | **DHS 2, 1992** | | | | | **DHS 3, 1996** | | | | |
| **15-19** | 0.1453 | 0.1391 | 0.2156 | 1991.04 | 0.2279 | 0.1606 | 0.1678 | 0.3262 | 1995.79 | 0.2692 |
| **20-24** | 0.1938 | 0.1857 | 0.2482 | 1989.71 | 0.2396 | 0.1891 | 0.1832 | 0.2399 | 1994.40 | 0.2366 |
| **25-29** | 0.1626 | 0.1513 | 0.0514 | 1987.84 | 0.1753 | 0.1767 | 0.1624 | 0.0932 | 1992.38 | 0.1877 |
| **30-34** | 0.1714 | 0.1669 | 0.0219 | 1985.65 | 0.1669 | 0.1912 | 0.1826 | 0.0762 | 1989.98 | 0.1826 |
| **35-39** | 0.1550 | 0.1612 | -0.0910 | 1983.23 | 0.1378 | 0.1788 | 0.1819 | -0.0183 | 1987.32 | 0.1561 |
| **40-44** | 0.1884 | 0.1937 | -0.0260 | 1980.63 | 0.1540 | 0.1814 | 0.1826 | -0.0623 | 1984.50 | 0.1448 |
| **45-49** | 0.2149 | 0.2169 | -0.0028 | 1977.78 | 0.1602 | 0.2282 | 0.2262 | 0.0241 | 1981.60 | 0.1676 |
| | *P1/P2 = 0.2028; P2/P3 = 0.5165; Survey date = 1992.23* | | | | | *P1/P2 = 0.1790; P2/P3 = 0.5374; Survey date = 1996.80* | | | | |

### Zimbabwe

| | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | **DHS 1, 1988** | | | | | **Census, 1992** | | | | |
| **15-19** | 0.0729 | 0.0780 | -0.1080 | 1987.93 | 0.1339 | 0.0723 | 0.0718 | -0.1526 | 1991.52 | 0.1238 |
| **20-24** | 0.0669 | 0.0680 | -0.3216 | 1986.74 | 0.0916 | 0.0736 | 0.0737 | -0.2782 | 1990.34 | 0.0991 |
| **25-29** | 0.0875 | 0.0843 | -0.2792 | 1984.99 | 0.0989 | 0.0755 | 0.0730 | -0.3569 | 1988.70 | 0.0859 |
| **30-34** | 0.0816 | 0.0812 | -0.3874 | 1982.89 | 0.0812 | 0.0857 | 0.0862 | -0.3547 | 1986.74 | 0.0862 |
| **35-39** | 0.1008 | 0.1064 | -0.3306 | 1980.52 | 0.0901 | 0.1003 | 0.1073 | -0.3259 | 1984.55 | 0.0909 |
| **40-44** | 0.1106 | 0.1150 | -0.3330 | 1977.92 | 0.0897 | 0.1245 | 0.1313 | -0.2575 | 1982.10 | 0.1028 |
| **45-49** | 0.1305 | 0.1331 | -0.2978 | 1975.02 | 0.0956 | 0.1452 | 0.1499 | -0.2286 | 1979.25 | 0.1083 |
| | *P1/P2 = 0.1448; P2/P3 = 0.4488; Survey date = 1988.93* | | | | | *P1/P2 = 0.1688; P2/P3 = 0.4411; Census date = 1992.67* | | | | |
| | **DHS 3, 1994** | | | | | **DHS 4, 1999** | | | | |
| **15-19** | 0.0623 | 0.0665 | -0.1936 | 1993.77 | 0.1152 | 0.0724 | 0.0730 | -0.1438 | 1998.73 | 0.1258 |
| **20-24** | 0.0821 | 0.0818 | -0.2221 | 1992.49 | 0.1095 | 0.0838 | 0.0820 | -0.2206 | 1997.43 | 0.1098 |
| **25-29** | 0.0756 | 0.0712 | -0.3705 | 1990.60 | 0.0838 | 0.0908 | 0.0852 | -0.2734 | 1995.57 | 0.0999 |
| **30-34** | 0.0798 | 0.0778 | -0.4105 | 1988.35 | 0.0778 | 0.0720 | 0.0704 | -0.4649 | 1993.37 | 0.0704 |
| **35-39** | 0.0925 | 0.0958 | -0.3890 | 1985.82 | 0.0810 | 0.0756 | 0.0787 | -0.4968 | 1990.92 | 0.0663 |
| **40-44** | 0.1041 | 0.1064 | -0.3767 | 1983.10 | 0.0828 | 0.0950 | 0.0976 | -0.4248 | 1988.28 | 0.0758 |
| **45-49** | 0.1238 | 0.1245 | -0.3363 | 1980.19 | 0.0892 | 0.1220 | 0.1231 | -0.3426 | 1985.41 | 0.0882 |
| | *P1/P2 = 0.1573; P2/P3 = 0.4906; Survey date = 1994.76* | | | | | *P1/P2 = 0.1805; P2/P3 = 0.4996; Survey date = 1999.83* | | | | |

## Namibia

| | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Census, 1991** | | | | | **DHS 2, 1992** | | | | |
| **15-19** | 0.0688 | 0.0730 | -0.1438 | 1990.83 | 0.1258 | 0.0534 | 0.0525 | -0.3192 | 1991.58 | 0.0920 |
| **20-24** | 0.0793 | 0.0793 | -0.2388 | 1989.57 | 0.1063 | 0.0902 | 0.0873 | -0.1862 | 1990.26 | 0.1167 |
| **25-29** | 0.0899 | 0.0852 | -0.2730 | 1987.73 | 0.1000 | 0.0904 | 0.0844 | -0.2785 | 1988.39 | 0.0990 |
| **30-34** | 0.1065 | 0.1045 | -0.2487 | 1985.52 | 0.1045 | 0.1054 | 0.1028 | -0.2578 | 1986.20 | 0.1028 |
| **35-39** | 0.1165 | 0.1214 | -0.2562 | 1983.05 | 0.1031 | 0.1060 | 0.1102 | -0.3108 | 1983.76 | 0.0934 |
| **40-44** | 0.1410 | 0.1450 | -0.1999 | 1980.38 | 0.1139 | 0.1227 | 0.1261 | -0.2807 | 1981.13 | 0.0986 |
| **45-49** | 0.1553 | 0.1568 | -0.2018 | 1977.48 | 0.1136 | 0.1261 | 0.1272 | -0.3239 | 1978.27 | 0.0912 |
| | *P1/P2 = 0.1565; P2/P3 =0.4795; Census date = 1991.83* | | | | | *P1/P2 = 0.1918; P2/P3 =0.5089; Survey date = 1992.72* | | | | |

## Mozambique

| | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ |
|---|---|---|---|---|---|
| | **DHS 3, 1997** | | | | |
| **15-19** | 0.1252 | 0.1182 | 0.0640 | 1996.11 | 0.1768 |
| **20-24** | 0.1704 | 0.1681 | 0.1388 | 1994.63 | 0.1996 |
| **25-29** | 0.1912 | 0.1852 | 0.1462 | 1992.55 | 0.2020 |
| **30-34** | 0.2008 | 0.1987 | 0.1359 | 1990.17 | 0.1987 |
| **35-39** | 0.2133 | 0.2156 | 0.1316 | 1987.59 | 0.1973 |
| **40-44** | 0.2143 | 0.2142 | 0.0877 | 1984.90 | 0.1838 |
| **45-49** | 0.2440 | 0.2419 | 0.1143 | 1982.04 | 0.1919 |
| | *P1/P2 = 0.2296; P2/P3 = 0.5534; Survey date = 1997.38* | | | | |

## South Africa

| | Proportions Dead of CEB | $q(x)$ | alpha | date | $q(5)$ |
|---|---|---|---|---|---|
| | **DHS 3, 1998** | | | | |
| **15-19** | 0.0648 | 0.0656 | -0.2589 | 1997.27 | 0.1012 |
| **20-24** | 0.0624 | 0.0640 | -0.4032 | 1995.92 | 0.0778 |
| **25-29** | 0.0571 | 0.0565 | -0.5204 | 1993.99 | 0.0626 |
| **30-34** | 0.0640 | 0.0643 | -0.5054 | 1991.72 | 0.0643 |
| **35-39** | 0.0799 | 0.0818 | -0.4316 | 1989.23 | 0.0738 |
| **40-44** | 0.0999 | 0.1012 | -0.3545 | 1986.57 | 0.0851 |
| **45-49** | 0.1290 | 0.1296 | -0.2669 | 1983.66 | 0.0998 |
| | *P1/P2 = 0.1873; P2/P3 = 0.4943; Survey date = 1998.42* | | | | |

## Malawi

| | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) | Proportions Dead of CEB | *q*(*x*) | alpha | date | *q*(5) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Census, 1977** | | | | | **Demographic Survey, 1982** | | | | |
| **15-19** | 0.2473 | 0.2125 | 0.4720 | 1976.48 | 0.3302 | 0.2035 | 0.1853 | 0.3865 | 1981.57 | 0.2936 |
| **20-24** | 0.2740 | 0.2505 | 0.4394 | 1975.06 | 0.3160 | 0.2279 | 0.2144 | 0.3378 | 1980.20 | 0.2738 |
| **25-29** | 0.3099 | 0.2821 | 0.4464 | 1973.13 | 0.3190 | 0.2646 | 0.2446 | 0.3497 | 1978.33 | 0.2785 |
| **30-34** | 0.3395 | 0.3271 | 0.4650 | 1970.93 | 0.3271 | 0.3023 | 0.2939 | 0.3874 | 1976.16 | 0.2939 |
| **35-39** | 0.3618 | 0.3740 | 0.4760 | 1968.52 | 0.3320 | 0.3337 | 0.3471 | 0.4176 | 1973.78 | 0.3066 |
| **40-44** | 0.3835 | 0.3925 | 0.4688 | 1965.95 | 0.3288 | 0.3644 | 0.3749 | 0.4316 | 1971.21 | 0.3126 |
| **45-49** | 0.4076 | 0.4096 | 0.4563 | 1963.15 | 0.3233 | 0.3928 | 0.3966 | 0.4293 | 1968.39 | 0.3116 |
| | *P1/P2 = 0.2489; P2/P3 = 0.5601; Census date = 1977.83* | | | | | *P1/P2 = 0.2228; P2/P3 = 0.5302; Census date = 1982.83* | | | | |
| | **Census, 1987** | | | | | **DHS 2, 1992** | | | | |
| **15-19** | 0.2094 | 0.1896 | 0.4008 | 1986.48 | 0.2995 | 0.2076 | 0.2050 | 0.4492 | 1991.66 | 0.3202 |
| **20-24** | 0.2221 | 0.2072 | 0.3165 | 1985.09 | 0.2653 | 0.2160 | 0.2091 | 0.3221 | 1990.34 | 0.2675 |
| **25-29** | 0.2397 | 0.2200 | 0.2805 | 1983.17 | 0.2516 | 0.2316 | 0.2162 | 0.2694 | 1988.46 | 0.2474 |
| **30-34** | 0.2658 | 0.2568 | 0.2944 | 1980.96 | 0.2568 | 0.2238 | 0.2180 | 0.1868 | 1986.25 | 0.2180 |
| **35-39** | 0.2942 | 0.3044 | 0.3204 | 1978.54 | 0.2669 | 0.2369 | 0.2461 | 0.1737 | 1983.80 | 0.2135 |
| **40-44** | 0.3239 | 0.3316 | 0.3366 | 1975.94 | 0.2733 | 0.2730 | 0.2801 | 0.2153 | 1981.16 | 0.2278 |
| **45-49** | 0.3509 | 0.3528 | 0.3357 | 1973.11 | 0.2729 | 0.3217 | 0.3242 | 0.2718 | 1978.30 | 0.2483 |
| | *P1/P2 = 0.2283; P2/P3 = 0.5437; Census date = 1987.75* | | | | | *P1/P2 = 0.1907; P2/P3 = 0.5101; Survey date = 1992.79* | | | | |

# Appendix 4

# Interpolated $l_x$ and ${}_nm_x$ Values in Childhood for Princeton Life Tables of Level 15, Both Sexes

**Table A4.1:** ***Fitted models for the Level 15 Princeton Life Tables for Both Sexes.***

| Age | North Level 15 (Both Sexes) | | South Level 15 (Both Sexes) | | East Level 15 (Both Sexes) | | West Level 15 (Both Sexes) | |
|---|---|---|---|---|---|---|---|---|
| (in months) | $l_x$ | Fitted $l_x$ | $l_x$ | Fitted $l_x$ | $l_x$ | Fitted $l_x$ | $l_x$ | Fitted $l_x$ |
| 0 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 1 | | 0.9771 | | 0.9668 | | 0.9369 | | 0.9629 |
| 2 | | 0.9625 | | 0.9477 | | 0.9188 | | 0.9466 |
| 3 | | 0.9519 | | 0.9344 | | 0.9080 | | 0.9360 |
| 4 | | 0.9435 | | 0.9241 | | 0.9003 | | 0.9283 |
| 5 | | 0.9366 | | 0.9158 | | 0.8943 | | 0.9221 |
| 6 | | 0.9307 | | 0.9089 | | 0.8894 | | 0.9171 |
| 7 | | 0.9256 | | 0.9029 | | 0.8853 | | 0.9127 |
| 8 | | 0.9211 | | 0.8976 | | 0.8817 | | 0.9090 |
| 9 | | 0.9171 | | 0.8930 | | 0.8786 | | 0.9056 |
| 10 | | 0.9134 | | 0.8888 | | 0.8758 | | 0.9027 |
| 11 | | 0.9101 | | 0.8849 | | 0.8733 | | 0.9000 |
| 12 | 0.9071 | 0.9071 | 0.8814 | 0.8814 | 0.8709 | 0.8709 | 0.8975 | 0.8975 |
| 13 | | 0.9042 | | 0.8782 | | 0.8688 | | 0.8952 |
| 14 | | 0.9016 | | 0.8752 | | 0.8669 | | 0.8931 |
| 15 | | 0.8992 | | 0.8724 | | 0.8650 | | 0.8912 |
| 16 | | 0.8969 | | 0.8698 | | 0.8633 | | 0.8893 |
| 17 | | 0.8947 | | 0.8673 | | 0.8617 | | 0.8876 |
| 18 | | 0.8926 | | 0.8650 | | 0.8602 | | 0.8860 |
| 19 | | 0.8907 | | 0.8628 | | 0.8588 | | 0.8844 |
| 20 | | 0.8888 | | 0.8607 | | 0.8575 | | 0.8830 |
| 21 | | 0.8871 | | 0.8587 | | 0.8562 | | 0.8816 |
| 22 | | 0.8854 | | 0.8568 | | 0.8550 | | 0.8803 |
| 23 | | 0.8838 | | 0.8550 | | 0.8538 | | 0.8790 |
| 24 | 0.8834 | 0.8823 | 0.8461 | 0.8533 | 0.8487 | 0.8527 | 0.8743 | 0.8778 |
| 25 | | 0.8808 | | 0.8517 | | 0.8516 | | 0.8767 |
| 26 | | 0.8794 | | 0.8501 | | 0.8506 | | 0.8756 |
| 27 | | 0.8780 | | 0.8485 | | 0.8496 | | 0.8745 |
| 28 | | 0.8767 | | 0.8470 | | 0.8487 | | 0.8735 |
| 29 | | 0.8754 | | 0.8456 | | 0.8478 | | 0.8725 |
| 30 | | 0.8742 | | 0.8442 | | 0.8469 | | 0.8715 |
| 31 | | 0.8730 | | 0.8429 | | 0.8460 | | 0.8706 |
| 32 | | 0.8719 | | 0.8416 | | 0.8452 | | 0.8697 |
| 33 | | 0.8707 | | 0.8404 | | 0.8444 | | 0.8688 |

**Table A4.1 — *continued.***

| Age | North Level 15 (Both Sexes) | | South Level 15 (Both Sexes) | | East Level 15 (Both Sexes) | | West Level 15 (Both Sexes) | |
|---|---|---|---|---|---|---|---|---|
| (in months) | $l_x$ | Fitted $l_x$ | $l_x$ | Fitted $l_x$ | $l_x$ | Fitted $l_x$ | $l_x$ | Fitted $l_x$ |
| 34 | | 0.8697 | | 0.8392 | | 0.8436 | | 0.8680 |
| 35 | | 0.8686 | | 0.8380 | | 0.8429 | | 0.8672 |
| 36 | 0.8687 | 0.8676 | 0.8299 | 0.8369 | 0.8394 | 0.8422 | 0.8640 | 0.8664 |
| 37 | | 0.8666 | | 0.8358 | | 0.8414 | | 0.8656 |
| 38 | | 0.8656 | | 0.8347 | | 0.8408 | | 0.8649 |
| 39 | | 0.8647 | | 0.8336 | | 0.8401 | | 0.8642 |
| 40 | | 0.8638 | | 0.8326 | | 0.8394 | | 0.8634 |
| 41 | | 0.8629 | | 0.8316 | | 0.8388 | | 0.8628 |
| 42 | | 0.8620 | | 0.8306 | | 0.8382 | | 0.8621 |
| 43 | | 0.8612 | | 0.8297 | | 0.8376 | | 0.8614 |
| 44 | | 0.8603 | | 0.8288 | | 0.8370 | | 0.8608 |
| 45 | | 0.8595 | | 0.8279 | | 0.8364 | | 0.8601 |
| 46 | | 0.8587 | | 0.8270 | | 0.8358 | | 0.8595 |
| 47 | | 0.8579 | | 0.8261 | | 0.8353 | | 0.8589 |
| 48 | 0.8576 | 0.8572 | 0.8212 | 0.8253 | 0.8333 | 0.8347 | 0.8572 | 0.8583 |
| 49 | | 0.8564 | | 0.8244 | | 0.8342 | | 0.8578 |
| 50 | | 0.8557 | | 0.8236 | | 0.8337 | | 0.8572 |
| 51 | | 0.8550 | | 0.8228 | | 0.8332 | | 0.8567 |
| 52 | | 0.8543 | | 0.8221 | | 0.8327 | | 0.8561 |
| 53 | | 0.8536 | | 0.8213 | | 0.8322 | | 0.8556 |
| 54 | | 0.8529 | | 0.8206 | | 0.8317 | | 0.8551 |
| 55 | | 0.8523 | | 0.8198 | | 0.8313 | | 0.8545 |
| 56 | | 0.8516 | | 0.8191 | | 0.8308 | | 0.8540 |
| 57 | | 0.8510 | | 0.8184 | | 0.8303 | | 0.8536 |
| 58 | | 0.8504 | | 0.8177 | | 0.8299 | | 0.8531 |
| 59 | | 0.8497 | | 0.8170 | | 0.8295 | | 0.8526 |
| 60 | 0.8491 | 0.8491 | 0.8164 | 0.8164 | 0.8290 | 0.8290 | 0.8521 | 0.8521 |

***Model Coefficients:***

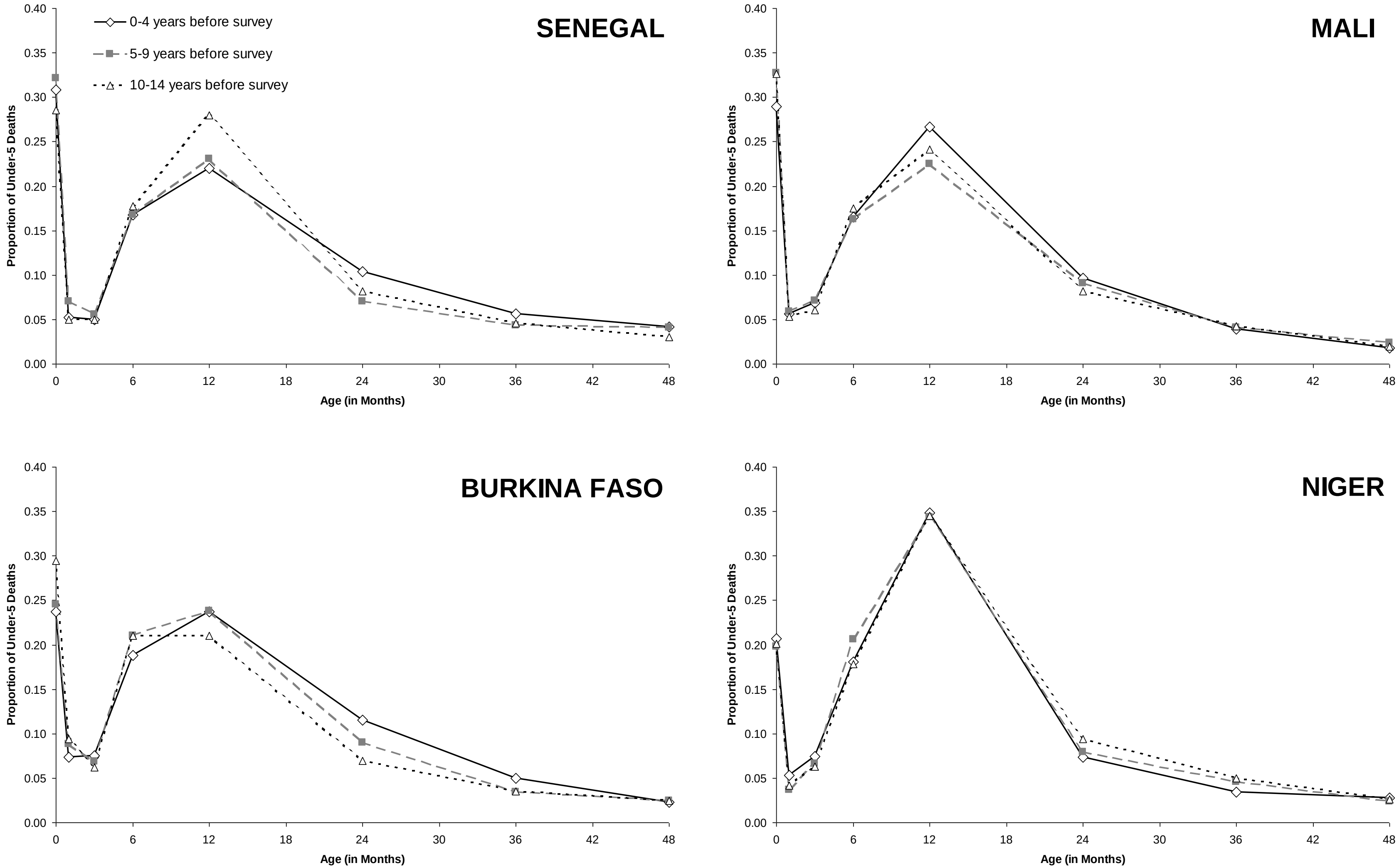
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | R = | 0.5964 | R = | 0.6219 | R = | 0.7370 | R = | 0.6759 |
| | Alpha = | 0.7055 | Alpha = | 0.9738 | Alpha = | 7.3082 | Alpha = | 2.1612 |
| | Beta = | 0.0434 | Beta = | 0.0497 | Beta = | 0.0308 | Beta = | 0.0328 |

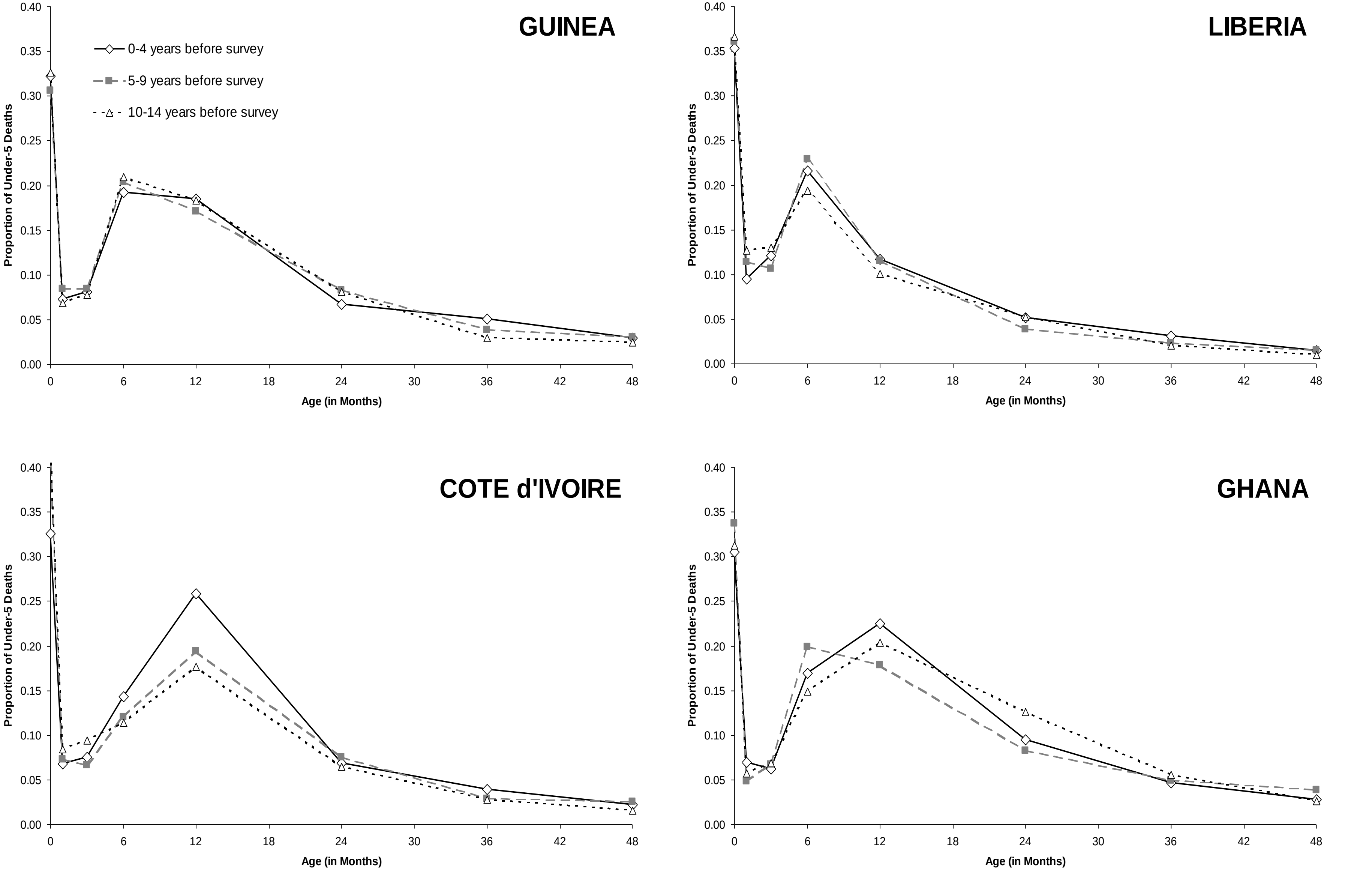
**Table A4.2:** ***Fitted Age-Specific Death Rates, $_{n}m_{x}$, for the Level 15 Princeton Life Tables for Both Sexes.***

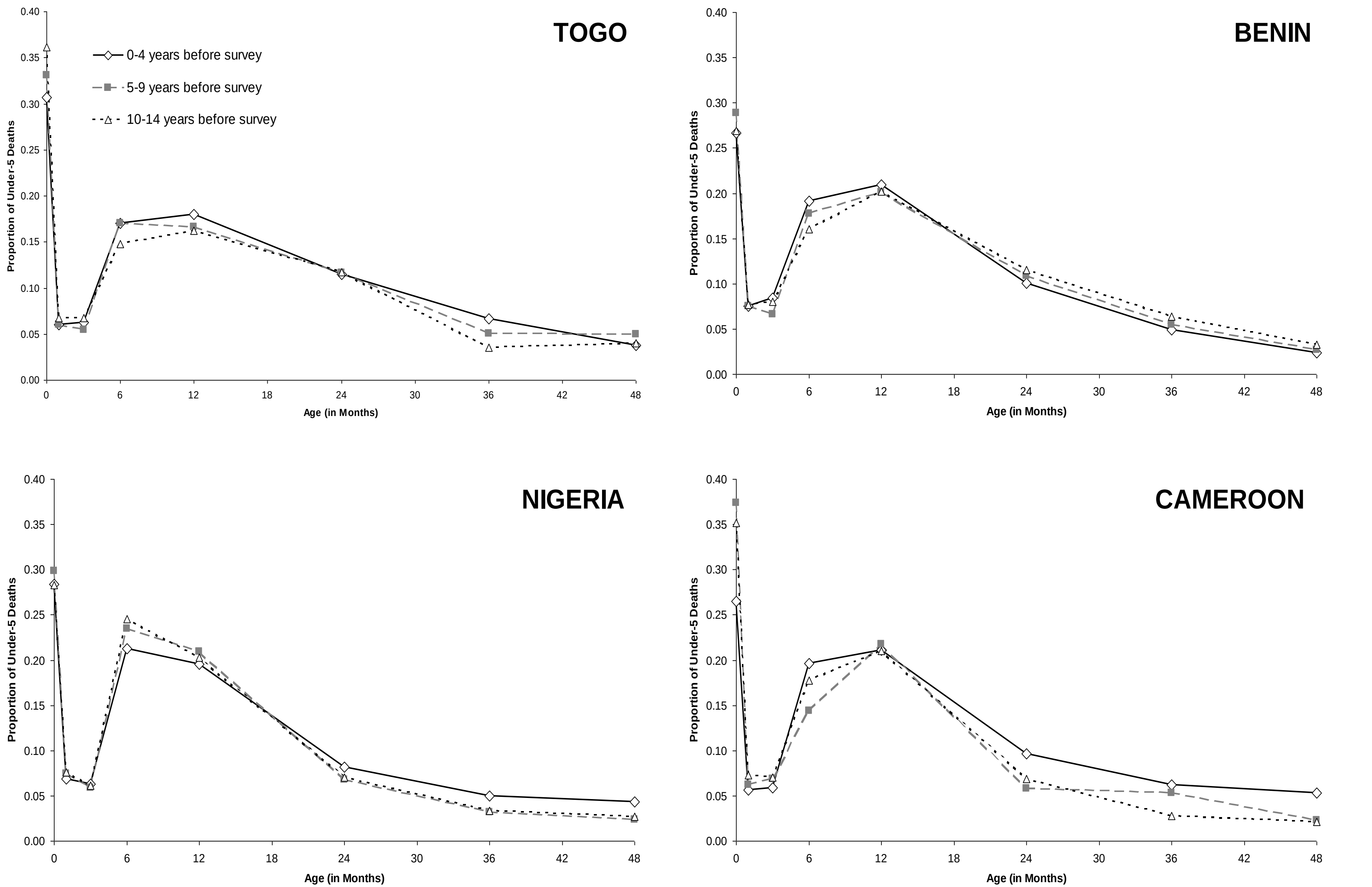
| **Age (in months)** | **North Level 15 (Both Sexes)** | **South Level 15 (Both Sexes)** | **East Level 15 (Both Sexes)** | **West Level 15 (Both Sexes)** |
|---|---|---|---|---|
| 0 | 0.2780 | 0.4053 | 0.7825 | 0.4535 |
| 1-2 | 0.1571 | 0.2049 | 0.1880 | 0.1700 |
| 3-5 | 0.0900 | 0.1108 | 0.0828 | 0.0820 |
| 6-8 | 0.0590 | 0.0707 | 0.0491 | 0.0501 |
| 9-14 | 0.0395 | 0.0466 | 0.0311 | 0.0323 |
| 15-23 | 0.0253 | 0.0295 | 0.0192 | 0.0201 |
| 24-35 | 0.0168 | 0.0194 | 0.0111 | 0.0119 |
| 36-47 | 0.0128 | 0.0105 | 0.0072 | 0.0078 |
| 48-59 | 0.0099 | 0.0059 | 0.0052 | 0.0060 |

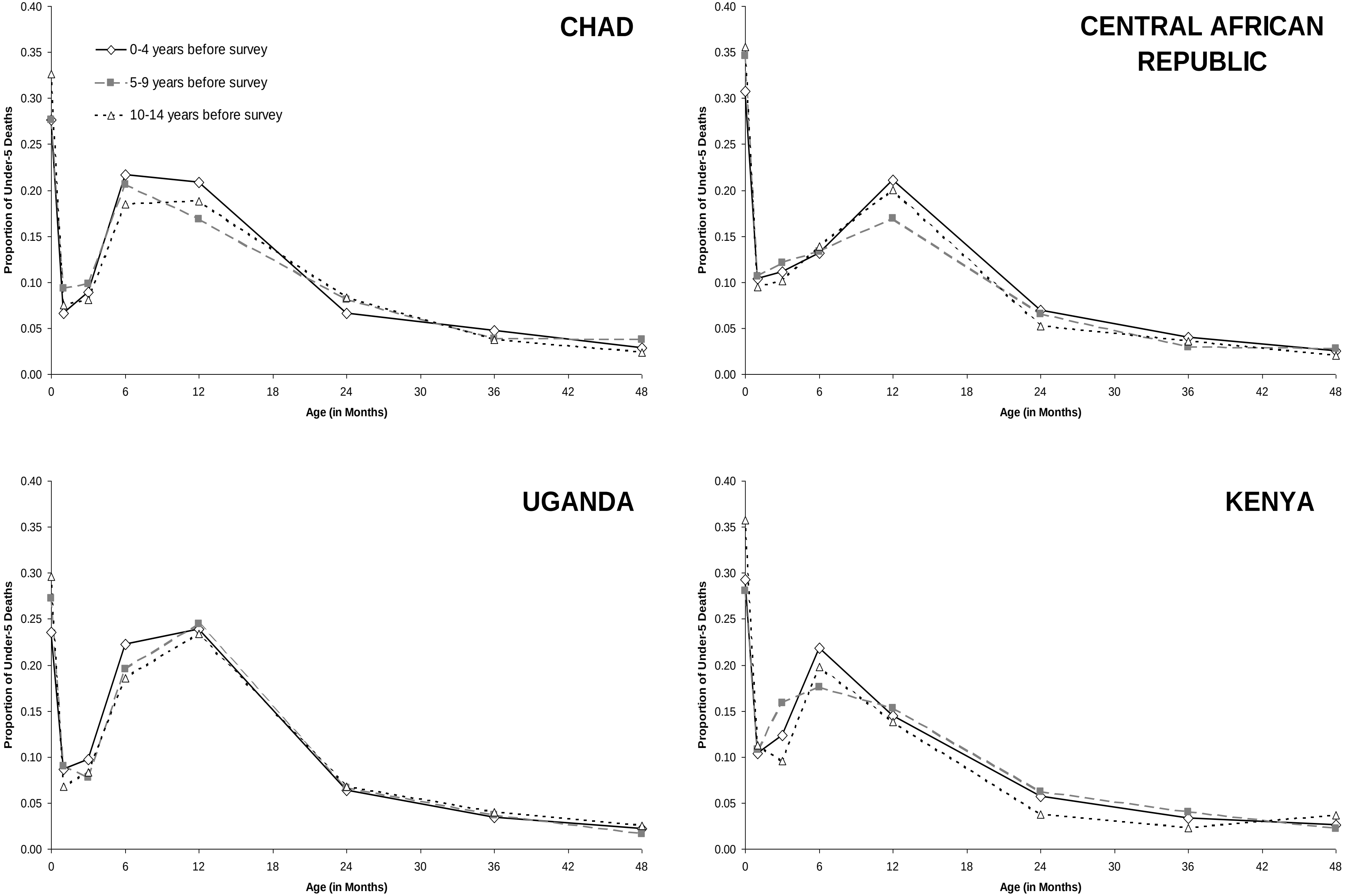
# Appendix 5

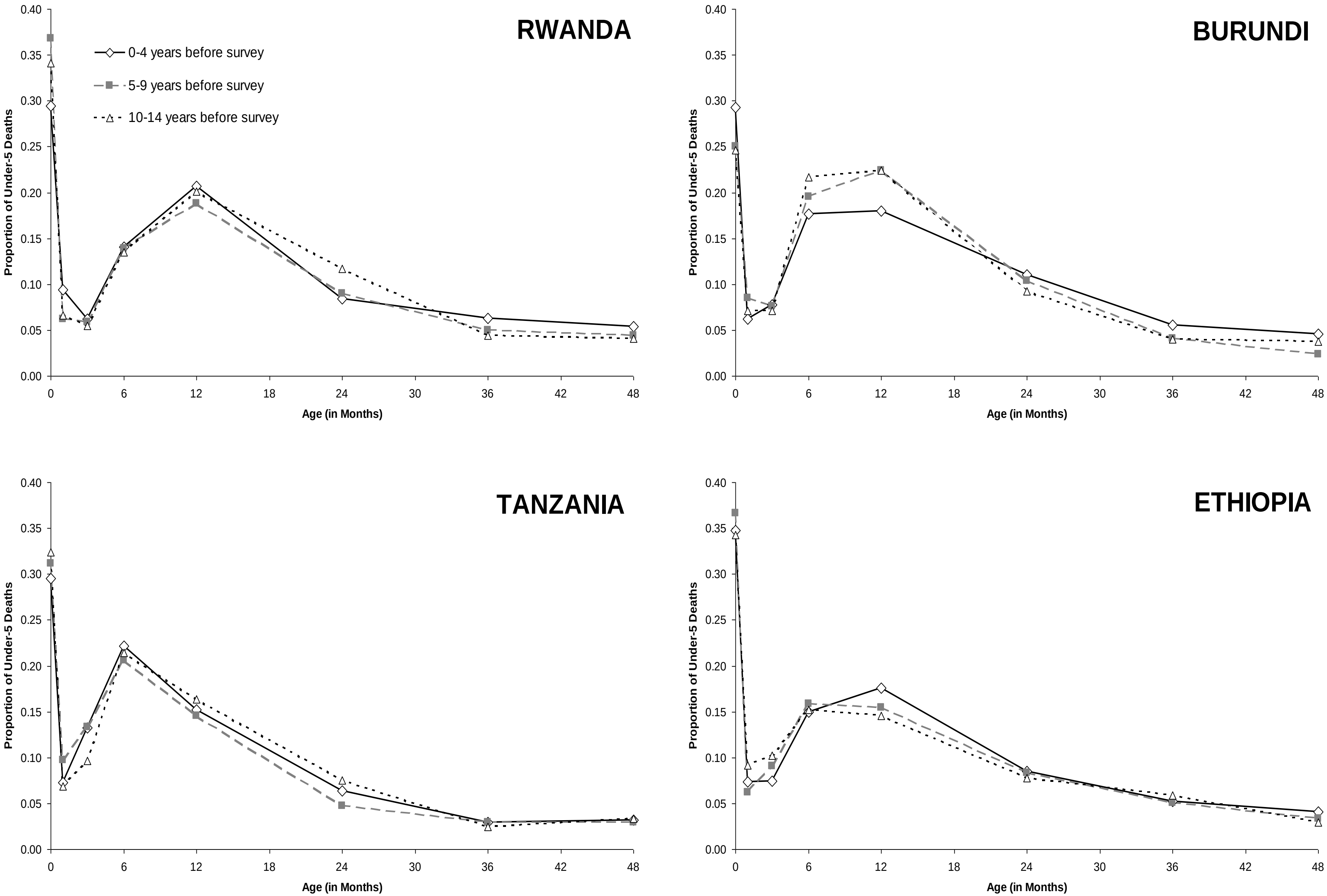
# Age Structures of Death in Childhood Depicted by Most Recent National Surveys

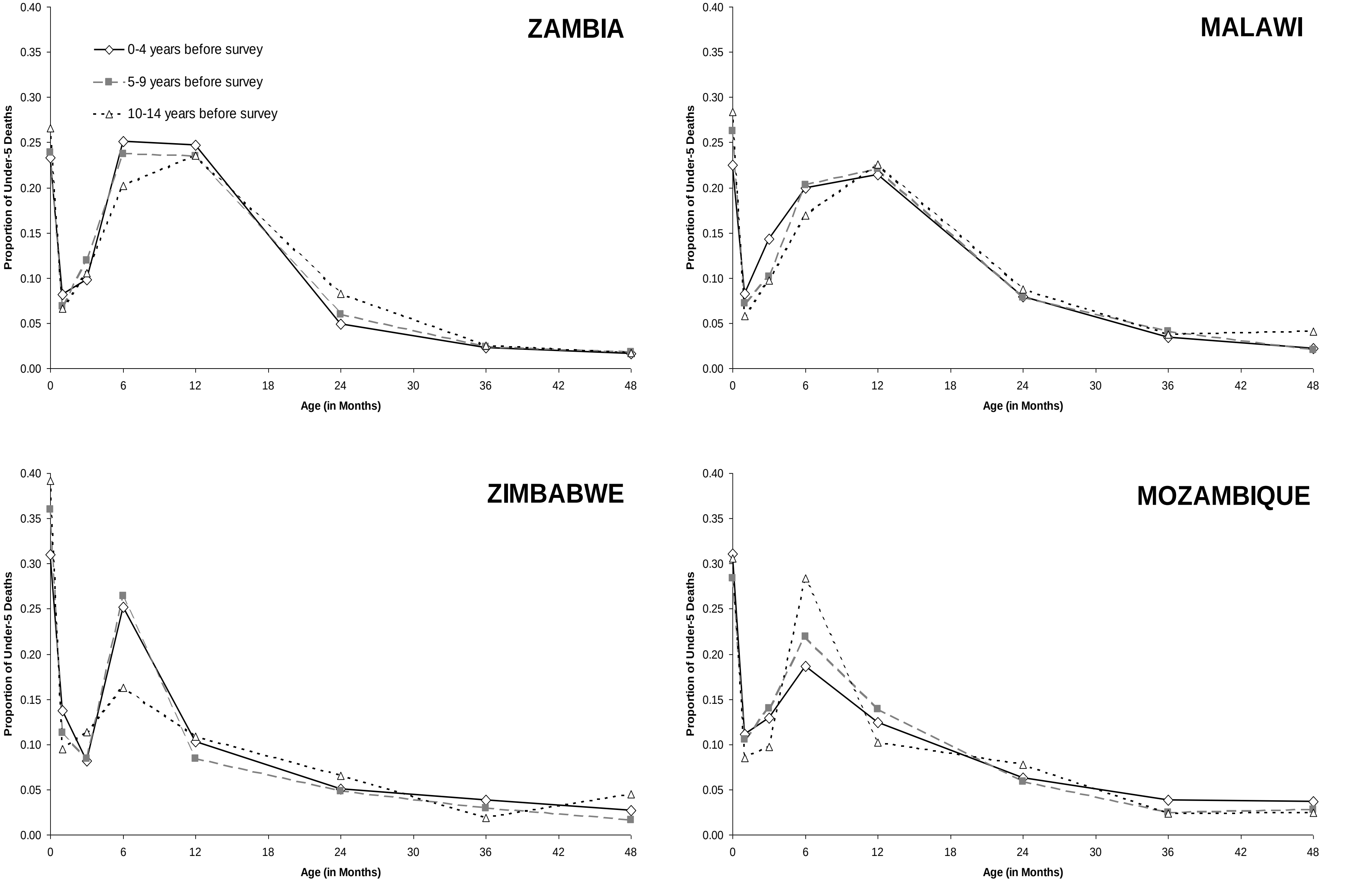


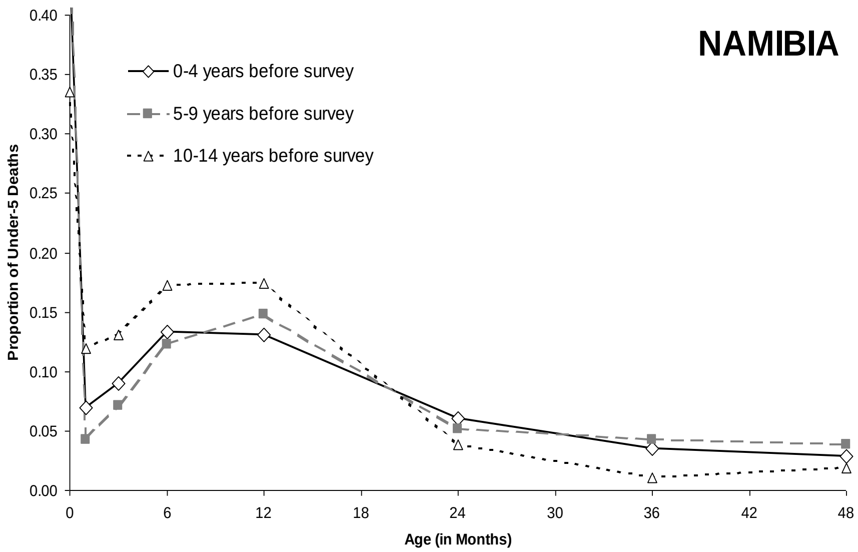

GUINEA
LIBERIA
COTE d'IVOIRE
GHANA
0-4 years before survey
5-9 years before survey
10-14 years before survey
Proportion of Under-5 Deaths
Age (in Months)

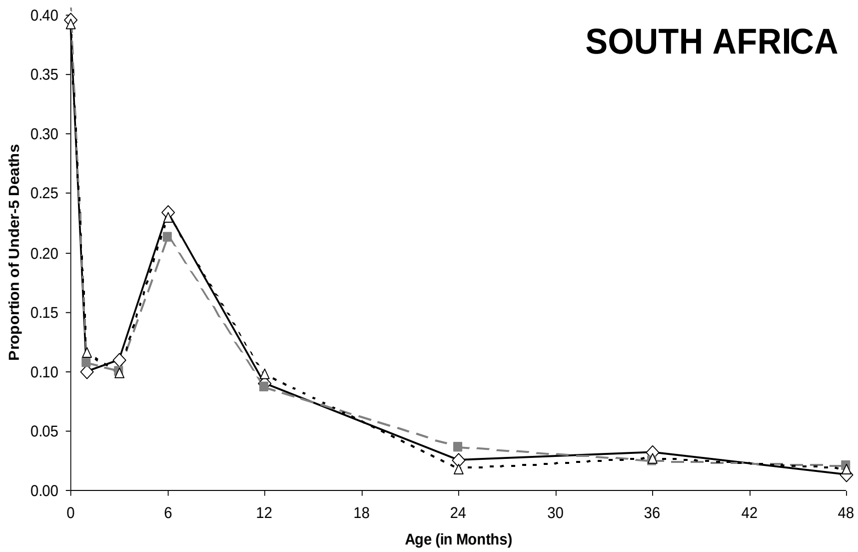

TOGO
BENIN
NIGERIA
CAMEROON
0-4 years before survey
5-9 years before survey
10-14 years before survey
Proportion of Under-5 Deaths
Age (in Months)


CHAD
CENTRAL AFRICAN REPUBLIC
UGANDA
KENYA
0-4 years before survey
5-9 years before survey
10-14 years before survey
Proportion of Under-5 Deaths
Age (in Months)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0
6
12
18
24
30
36
42
48


RWANDA
BURUNDI
TANZANIA
ETHIOPIA
0-4 years before survey
5-9 years before survey
10-14 years before survey
Proportion of Under-5 Deaths
Age (in Months)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0
6
12
18
24
30
36
42
48


ZAMBIA
MALAWI
ZIMBABWE
MOZAMBIQUE
0-4 years before survey
5-9 years before survey
10-14 years before survey
Proportion of Under-5 Deaths
Age (in Months)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
6
12
18
24
30
36
42
48


NAMIBIA
0-4 years before survey
5-9 years before survey
10-14 years before survey
Proportion of Under-5 Deaths
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
6
12
18
24
30
36
42
48
Age (in Months)


SOUTH AFRICA
Proportion of Under-5 Deaths
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
6
12
18
24
30
36
42
48
Age (in Months)

# Appendix 6

# Regression Coefficients Determining the Sizes and Explaining Variations in Derived National and Sub-national Values of $\alpha$

## 6.7 SAHEL WEST AFRICA

| **Country** | $\alpha_i$ | | | |
|---|---|---|---|---|
| **Region** | $\lambda_0$ | $\lambda_i$ | $\lambda_{t.i}$ | $R^2$ |
| **Senegal** | **0.1534** ***(0.0348)*** | | **-0.0076** ***(0.0060)*** | **0.6208** |
| *Sub-national regions* | 0.0045 *(0.0734)* | | -0.0180 *(0.0126)* | 0.5691 |
| Senegal West | | — | — | |
| Senegal Central | | -0.0531 *(0.0919)* | 0.0158 *(0.0158)* | |
| Senegal North East | | 0.4128 *(0.1129)* | 0.0168 *(0.0192)* | |
| Senegal South | | 0.8176 *(0.1070)* | -0.0078 *(0.0183)* | |
| **Mali** | **0.8927** ***(0.0309)*** | | **-0.0176** ***(0.0054)*** | **0.7025** |
| *Sub-national regions* | 0.9251 *(0.0557)* | | -0.0012 *(0.0097)* | 0.7358 |
| Kayes/Koulikoro | | — | — | |
| Sikasso/Segou | | 0.2241 *(0.0751)* | -0.0293 *(0.0131)* | |
| Mopti/Gao/Timbouctou | | -0.2288 *(0.0840)* | -0.0214 *(0.0146)* | |
| Bamako | | -0.3709 *(0.1425)* | 0.0036 *(0.0246)* | |
| **Burkina Faso** | **0.7865** ***(0.0456)*** | | **-0.0408** ***(0.0072)*** | **0.7186** |
| *Sub-national regions* | 0.8041 *(0.0840)* | | -0.0450 *(0.0132)* | 0.7315 |
| Ouagadougou | | -0.6482 *(0.2175)* | 0.0185 *(0.0374)* | |
| Burkina North | | -0.0785 *(0.1381)* | -0.0002 *(0.0222)* | |
| Burkina East | | 0.2471 *(0.1225)* | -0.0258 *(0.0192)* | |
| Burkina West | | -0.1289 *(0.1290)* | 0.0370 *(0.0202)* | |
| Burkina Central/South | | — | — | |
| **Niger** | **0.1456** ***(0.0371)*** | | **-0.0014** ***(0.0062)*** | **0.6105** |
| *Sub-national regions* | 0.1942 *(0.0758)* | | -0.0179 *(0.0125)* | 0.6589 |
| Niamey | | -1.0416 *(0.2563)* | 0.0880 *(0.0402)* | |
| Dosso | | -0.0136 *(0.1274)* | -0.0011 *(0.0216)* | |
| Maradi | | 0.0933 *(0.1063)* | 0.0420 *(0.0174)* | |
| Tahoua/Agadez | | -0.2055 *(0.1111)* | 0.0036 *(0.0188)* | |
| Tillaberi | | 0.0457 *(0.1220)* | 0.0092 *(0.0201)* | |
| Zinda/Diffa | | — | — | |

## 6.8 COASTAL WEST AFRICA

| **Country** Region | $\alpha_i$ $\lambda_0$ | $\lambda_i$ | $\lambda_{t.i}$ | $R^2$ |
|---|---|---|---|---|
| **Guinea** | **0.9204** ***(0.1024)*** | | **-0.0132** ***(0.0126)*** | **0.7474** |
| *Sub-national regions* | 0.8925 *(0.2271)* | | -0.0621 *(0.0284)* | 0.7663 |
| Lower Guinea | | — | — | |
| Central Guinea | | 0.1253 *(0.3076)* | 0.0413 *(0.0389)* | |
| Upper Guinea | | 0.1328 *(0.3184)* | 0.0627 *(0.0392)* | |
| Forest Guinea | | 0.0443 *(0.3027)* | 0.0780 *(0.0373)* | |
| Conakry | | -0.2164 *(0.4266)* | 0.0375 *(0.0516)* | |
| **Liberia** | **1.4692** ***(0.0951)*** | | **-0.0327** ***(0.0141)*** | **0.8626** |
| *Sub-national regions* | 1.9326 *(0.5299)* | | -0.0617 *(0.0751)* | 0.8689 |
| Sinoe | | — | — | |
| Grand Gedeh | | -0.5570 *(0.6341)* | 0.0521 *(0.0903)* | |
| Montserrado | | -0.7108 *(0.5631)* | 0.0290 *(0.0804)* | |
| Rest of Liberia | | -0.3776 *(0.5431)* | 0.0289 *(0.0771)* | |
| **Côte d'Ivoire** | **1.0989** ***(0.0659)*** | | **-0.0518** ***(0.0137)*** | **0.7039** |
| *Sub-national regions* | 0.8303 *(0.2602)* | | 0.0144 *(0.0542)* | 0.7280 |
| CI Centre | | — | — | |
| CI Centre North | | 0.7881 *(0.3659)* | -0.0590 *(0.0776)* | |
| CI North East | | -0.0168 *(0.3897)* | -0.0902 *(0.0841)* | |
| CI Centre East | | -1.5060 *(0.5221)* | 0.2377 *(0.0990)* | |
| CI South | | 0.0552 *(0.2893)* | -0.0824 *(0.0603)* | |
| CI South West | | 0.3565 *(0.3819)* | -0.1162 *(0.0784)* | |
| CI Centre West | | 0.0347 *(0.3012)* | -0.0314 *(0.0631)* | |
| CI West | | 0.8451 *(0.3206)* | -0.1351 *(0.0659)* | |
| CI West | | 0.2374 *(0.3829)* | -0.0976 *(0.0788)* | |
| CI North | | 1.3219 *(0.3585)* | -0.0711 *(0.0741)* | |
| **Ghana** | **0.4924** ***(0.0483)*** | | **-0.0347** ***(0.0082)*** | **0.5396** |
| *Sub-national regions* | 0.4503 *(0.1241)* | | -0.0373 *(0.0213)* | 0.5768 |
| Ghana Western | | -0.0007 *(0.1975)* | 0.0592 *(0.0329)* | |
| Ghana Central | | 0.7317 *(0.1819)* | -0.0050 *(0.0308)* | |
| Greater Accra | | 0.2249 *(0.2091)* | -0.0447 *(0.0358)* | |
| Volta | | -0.2659 *(0.1863)* | 0.0021 *(0.0319)* | |
| Ghana Eastern | | -0.1687 *(0.1940)* | 0.0041 *(0.0329)* | |
| Ashanti | | — | — | |
| Brong-Ahafo | | -0.0011 *(0.1928)* | 0.0404 *(0.0337)* | |
| Ghana Northern | | -0.1024 *(0.2268)* | 0.0038 *(0.0393)* | |
| Ghana Upper West | | -0.5904 *(0.3560)* | 0.0658 *(0.0593)* | |
| Ghana Upper East | | 0.5643 *(0.2518)* | -0.0728 *(0.0452)* | |

| Country | $\alpha_i$ | | | |
|---|---|---|---|---|
| Region | $\lambda_0$ | $\lambda_i$ | $\lambda_{t.i}$ | $R^2$ |
| **Togo** | **0.3829** ***(0.0502)*** | | **-0.0158** ***(0.0075)*** | **0.6533** |
| *Sub-national regions* | 0.2829 *(0.1535)* | | -0.0269 *(0.0229)* | 0.6684 |
| Maritime | | 0.3214 *(0.1747)* | 0.0024 *(0.0262)* | |
| des Plateaux | | 0.2388 *(0.1855)* | 0.0036 *(0.0276)* | |
| Togo Centrale | | — | — | |
| de la Kara | | -0.2863 *(0.2049)* | 0.0444 *(0.0306)* | |
| des Savanes | | -0.1577 *(0.2020)* | 0.0187 *(0.0303)* | |
| **Benin** | **0.3627** ***(0.0842)*** | | **0.0047** ***(0.0145)*** | **0.6597** |
| *Sub-national regions* | 0.7177 *(0.1937)* | | 0.0001 *(0.0324)* | 0.6851 |
| Atacora | | 0.2727 *(0.2619)* | -0.0572 *(0.0451)* | |
| Atlantique | | -0.3280 *(0.2946)* | -0.0238 *(0.0505)* | |
| Borgou | | — | — | |
| Mono | | -0.9870 *(0.3047)* | 0.1026 *(0.0505)* | |
| Oueme | | -0.4908 *(0.3050)* | -0.0052 *(0.0526)* | |
| Zou | | -0.7952 *(0.2860)* | 0.0193 *(0.0487)* | |
| **Nigeria** | **0.3090** ***(0.0402)*** | | **-0.0203** ***(0.0066)*** | **0.6479** |
| *Sub-national regions* | -0.3057 *(0.1073)* | | 0.0310 *(0.0156)* | 0.7146 |
| Nigeria North East | | — | — | |
| Nigeria North West | | 0.4552 *(0.1383)* | -0.0800 *(0.0213)* | |
| Nigeria South East | | 0.9626 *(0.1390)* | -0.0531 *(0.0215)* | |
| Nigeria South West | | 0.6479 *(0.1399)* | -0.0106 *(0.0215)* | |
| Nigeria Central | | 0.8950 *(0.1385)* | -0.0828 *(0.0218)* | |

## 6.9 MIDDLE AFRICA

| Country | $\alpha_i$ | | | |
|---|---|---|---|---|
| Region | $\lambda_0$ | $\lambda_i$ | $\lambda_{t.i}$ | $R^2$ |
| **Cameroon** | **0.6928** ***(0.0637)*** | | **-0.0602** ***(0.0104)*** | **0.6357** |
| *Sub-national regions* | 0.9668 *(0.0826)* | | -0.0593 *(0.0139)* | 0.6927 |
| North/Adamawa | | — | — | |
| Central/South/East | | -0.2461 *(0.1685)* | -0.0223 *(0.0268)* | |
| West/Littoral | | -0.7506 *(0.2084)* | 0.0410 *(0.0340)* | |
| Northwest/Southwest | | -0.8028 *(0.2147)* | 0.0103 *(0.0346)* | |
| **Central African Republic** | **0.9521** ***(0.0827)*** | | **-0.0188** ***(0.0162)*** | **0.7426** |
| *Sub-national regions* | 0.7040 *(0.1734)* | | 0.0144 *(0.0345)* | 0.7659 |
| CAR Health Region I | | 0.5552 *(0.2503)* | -0.0555 *(0.0482)* | |
| CAR Health Region II | | 0.1731 *(0.2480)* | -0.0077 *(0.0490)* | |
| CAR Health Region III | | — | — | |
| CAR Health Region IV | | 0.3797 *(0.3271)* | -0.0633 *(0.0660)* | |
| CAR Health Region V | | 0.6679 *(0.3179)* | 0.0118 *(0.0628)* | |
| Bangui | | 0.0384 *(0.2782)* | -0.1069 *(0.0561)* | |
| **Chad** | **0.7975** ***(0.0777)*** | | **-0.0256** ***(0.0119)*** | **0.6358** |
| *Sub-national regions* | 0.3829 *(0.3987)* | | -0.0205 *(0.0666)* | 0.6755 |
| Batha | | — | — | |
| Borkou-Ennedi-Tibesti | | -0.2092 *(1.1128)* | -0.1053 *(0.1873)* | |
| Biltine | | -0.3168 *(0.6415)* | 0.2565 *(0.1048)* | |
| Chari-Baguirmi | | 0.2076 *(0.4556)* | 0.0271 *(0.0745)* | |
| Guéra | | 0.0980 *(0.5243)* | 0.0429 *(0.0864)* | |
| Kanem | | -0.3902 *(0.5309)* | 0.0003 *(0.0862)* | |
| Lac | | -0.1207 *(0.7167)* | 0.0635 *(0.1038)* | |
| Logone Occidental | | 0.3671 *(0.5076)* | 0.0593 *(0.0849)* | |
| Logone Oriental | | 0.8703 *(0.4667)* | -0.0013 *(0.0762)* | |
| Mayo-Kébbi | | 1.2851 *(0.4662)* | -0.1117 *(0.0765)* | |
| Moyen Chari | | 0.6739 *(0.4764)* | -0.0216 *(0.0766)* | |
| Ouaddaï | | -0.0020 *(0.4643)* | 0.0183 *(0.0762)* | |
| Salamat | | 0.8530 *(0.5463)* | -0.1056 *(0.0894)* | |
| Tandjilé | | 1.1659 *(0.4692)* | -0.0627 *(0.0761)* | |
| N'Djamena | | -0.1184 *(0.5120)* | 0.0212 *(0.0809)* | |

## 6.10 EASTERN AFRICA

| Country / Region | $\alpha_i$ $\lambda_0$ | $\lambda_i$ | $\lambda_{t.i}$ | $\lambda_{T.i}$ | $R^2$ |
|---|---|---|---|---|---|
| **Uganda** | **0.7147 *(0.0576)*** | | **-0.0220 *(0.0086)*** | **-0.0049 *(0.0015)*** | **0.7493** |
| *Sub-national regions* | 0.6182 *(0.0937)* | | -0.0270 *(0.0174)* | -0.0079 *(0.0018)* | 0.7628 |
| Uganda Central | | — | — | — | |
| Uganda Eastern | | 0.2272 *(0.1212)* | 0.0181 *(0.0236)* | 0.0021 *(0.0014)* | |
| Uganda Northern | | -0.0703 *(0.1477)* | 0.0368 *(0.0292)* | 0.0027 *(0.0017)* | |
| Uganda Western | | 0.1748 *(0.1198)* | -0.0127 *(0.0232)* | 0.0045 *(0.0014)* | |
| **Rwanda** | **0.6239 *(0.0894)*** | | **-0.0182 *(0.0138)*** | **-0.0077 *(0.0045)*** | **0.6744** |
| **Burundi** | **0.0356 *(0.1155)*** | | **-0.0881 *(0.0270)*** | **-0.0072 *(0.0020)*** | **0.6240** |
| **Kenya** | **0.4772 *(0.0420)*** | | **0.0033 *(0.0072)*** | | **0.6631** |
| *Sub-national regions* | 0.3661 *(0.1416)* | | -0.0303 *(0.0207)* | 0.0057 *(0.0032)* | 0.7644 |
| Nairobi | | -0.4399 *(0.3129)* | 0.0300 *(0.0520)* | -0.0080 *(0.0072)* | |
| Kenya Central | | 0.0208 *(0.2656)* | 0.0459 *(0.0362)* | -0.0090 *(0.0057)* | |
| Kenya Coast | | 0.7809 *(0.2250)* | 0.0127 *(0.0306)* | -0.0089 *(0.0049)* | |
| Kenya Eastern | | — | — | — | |
| Nyanza | | 0.4966 *(0.1721)* | 0.0551 *(0.0259)* | -0.0059 *(0.0038)* | |
| Rift Valley | | 0.1913 *(0.1984)* | 0.0364 *(0.0293)* | -0.0075 *(0.0044)* | |
| Kenya Western | | -0.0674 *(0.1938)* | 0.0467 *(0.0291)* | -0.0159 *(0.0045)* | |
| **Tanzania** | **0.7737 *(0.0408)*** | | **0.0066 *(0.0069)*** | | **0.7415** |
| *Sub-national regions* | 0.7744 *(0.0748)* | | 0.0513 *(0.0172)* | -0.0050 *(0.0021)* | 0.7658 |
| Tanzania Coastal | | 0.2481 *(0.1220)* | -0.1067 *(0.0271)* | 0.0095 *(0.0033)* | |
| Tz Northern Highlands | | -0.3555 *(0.2035)* | -0.0917 *(0.0467)* | 0.0122 *(0.0050)* | |
| Lake | | — | — | — | |
| Tanzania Central | | 0.0343 *(0.1538)* | 0.0299 *(0.0352)* | -0.0013 *(0.0043)* | |
| Tz Southern Highlands | | -0.1093 *(0.1438)* | -0.0816 *(0.0323)* | 0.0080 *(0.0039)* | |
| Tanzania South | | -0.0333 *(0.1603)* | -0.0594 *(0.0346)* | 0.0107 *(0.0042)* | |
| **Ethiopia** | **0.9059 *(0.0892)*** | | **0.0549 *(0.0182)*** | **-0.0058 *(0.0010)*** | **0.7679** |
| *Sub-national regions* | 0.8272 *(0.0752)* | | -0.0752 *(0.0187)* | -0.0060 *(0.0010)* | 0.7802 |
| Tigray | | 0.3163 *(0.1571)* | 0.0387 *(0.0401)* | | |
| Affar | | -0.4306 *(0.3212)* | 0.1189 *(0.0819)* | | |
| Amhara | | 0.4135 *(0.1002)* | 0.0080 *(0.0256)* | | |
| Oromiya | | 0.1124 *(0.0922)* | 0.0790 *(0.0234)* | | |
| Somali | | -0.2953 *(0.3343)* | 0.1236 *(0.0857)* | | |
| Ben-Gumz | | 0.0442 *(0.3266)* | -0.0439 *(0.0834)* | | |
| SNNP | | — | — | | |
| Gambela | | -0.0992 *(0.6801)* | 0.0529 *(0.1757)* | | |
| Harari | | 0.0937 *(0.7980)* | 0.0295 *(0.2000)* | | |
| Addis | | 0.3101 *(0.4118)* | 0.0883 *(0.1022)* | | |
| Dire Dawa | | 0.2301 *(0.6403)* | -0.0466 *(0.1621)* | | |

## 6.11 SOUTHERN AFRICA

| Country | $\alpha_i$ | | | | |
|---|---|---|---|---|---|
| Region | $\lambda_0$ | $\lambda_i$ | $\lambda_{t.i}$ | $\lambda_{T.i}$ | $R^2$ |
| **Zambia** | **0.4522 *(0.0500)*** | | **0.0357 *(0.0096)*** | **-0.0013 *(0.0006)*** | **0.6663** |
| *Sub-national regions* | 0.6187 *(0.1431)* | | 0.0612 *(0.0303)* | -0.0067 *(0.0025)* | 0.7101 |
| Zambia Central | | -0.3606 *(0.2289)* | 0.0555 *(0.0498)* | 0.0014 *(0.0040)* | |
| Copperbelt | | -0.9934 *(0.1949)* | -0.0168 *(0.0396)* | 0.0099 *(0.0032)* | |
| Zambia Eastern | | 0.2323 *(0.1871)* | 0.0019 *(0.0402)* | 0.0002 *(0.0032)* | |
| Luapula | | 0.3711 *(0.2109)* | -0.0490 *(0.0435)* | 0.0043 *(0.0036)* | |
| Lusaka | | -0.3895 *(0.2044)* | -0.0309 *(0.0411)* | 0.0079 *(0.0034)* | |
| Zambia Northern | | — | — | — | |
| Zambia North-Western | | 0.2504 *(0.3135)* | -0.0361 *(0.0649)* | -0.0010 *(0.0053)* | |
| Zambia Southern | | -0.3545 *(0.2117)* | -0.0957 *(0.0419)* | 0.0106 *(0.0036)* | |
| Zambia Western | | 0.5453 *(0.2174)* | -0.0383 *(0.0452)* | 0.0058 *(0.0037)* | |
| **Malawi** | **0.7218 *(0.0560)*** | | **0.0017 *(0.0138)*** | | **0.7835** |
| *Sub-national regions* | 0.8373 *(0.1738)* | | -0.0171 *(0.0430)* | | 0.8040 |
| Malawi North | | — | — | | |
| Malawi Central | | -0.5195 *(0.1946)* | 0.0260 *(0.0481)* | | |
| Malawi South | | 0.2480 *(0.1921)* | 0.0169 *(0.0475)* | | |
| **Zimbabwe** | **0.4272 *(0.0668)*** | | **-0.0120 *(0.0099)*** | **0.0028 *(0.0005)*** | **0.5991** |
| *Sub-national regions* | 0.5228 *(0.1602)* | | -0.0296 *(0.0222)* | 0.0032 *(0.0011)* | 0.6270 |
| Manicaland | | — | — | — | |
| Mashonaland Central | | -0.1143 *(0.2681)* | 0.1455 *(0.0427)* | -0.0042 *(0.0020)* | |
| Mashonaland East | | -0.6594 *(0.2496)* | 0.0578 *(0.0362)* | 0.0017 *(0.0018)* | |
| Mashonaland West | | 0.4780 *(0.2457)* | -0.0207 *(0.0365)* | -0.0035 *(0.0018)* | |
| Matabeleland North | | 0.0784 *(0.3362)* | -0.0109 *(0.0535)* | -0.0030 *(0.0027)* | |
| Matabeleland South | | 0.7738 *(0.3855)* | 0.0462 *(0.0575)* | 0.0004 *(0.0024)* | |
| Zimbabwe Midlands | | 0.1218 *(0.2411)* | -0.0036 *(0.0339)* | 0.0009 *(0.0017)* | |
| Masvingo | | -0.3768 *(0.2466)* | 0.0686 *(0.0386)* | -0.0032 *(0.0019)* | |
| Harare Chitungwiza | | -0.2653 *(0.3190)* | -0.0867 *(0.0411)* | 0.0020 *(0.0021)* | |
| Bulawayo | | -0.0444 *(0.4400)* | -0.0085 *(0.0564)* | 0.0036 *(0.0027)* | |
| **Mozambique** | **1.0170 *(0.0797)*** | | **0.0935 *(0.0174)*** | **-0.0093 *(0.0013)*** | **0.6953** |
| *Sub-national regions* | 1.3403 *(0.3539)* | | -0.1088 *(0.0529)* | | 0.7485 |
| Niassa | | 0.0060 *(0.4555)* | 0.0462 *(0.0696)* | | |
| Cabo Delgado | | 0.8035 *(0.5363)* | -0.0695 *(0.0770)* | | |
| Nampula | | 0.7266 *(0.3876)* | 0.0740 *(0.0576)* | | |
| Zambezia | | -1.1049 *(0.4107)* | 0.2093 *(0.0610)* | | |
| Tete | | -0.3111 *(0.4489)* | 0.1146 *(0.0687)* | | |
| Manica | | — | — | | |
| Sofala | | -0.6812 *(0.4039)* | 0.1813 *(0.0596)* | | |
| Inhambane | | 0.0604 *(0.4582)* | 0.0980 *(0.0682)* | | |
| Gaza | | -0.8319 *(0.4503)* | 0.0894 *(0.0663)* | | |
| Maputo | | -1.3240 *(0.5541)* | 0.2339 *(0.0795)* | | |
| Cidade de Maputo | | -0.1813 *(0.5881)* | -0.0803 *(0.0889)* | | |

| Country / Region | $\alpha_i$: $\lambda_0$ | $\lambda_i$ | $\lambda_{t.i}$ | $\lambda_{T.i}$ | $R^2$ |
|---|---|---|---|---|---|
| **Namibia** | **0.8054 *(0.0951)*** | | **-0.0300 *(0.0232)*** | | **0.7057** |
| *Sub-national regions* | 0.8584 *(0.1521)* | | -0.0240 *(0.0369)* | | 0.7309 |
| Namibia Northwest | | — | — | | |
| Namibia Northeast | | -0.0920 *(0.2382)* | 0.0167 *(0.0580)* | | |
| Namibia Central | | -0.5661 *(0.3371)* | -0.0327 *(0.0818)* | | |
| Namibia South | | 0.2665 *(0.2550)* | -0.0092 *(0.0624)* | | |
| **South Africa** | **0.7774 *(0.1832)*** | | **-0.1067 *(0.0425)*** | **0.0093 *(0.0030)*** | **0.6773** |
| *Sub-national regions* | 0.9106 *(0.3811)* | | -0.0307 *(0.0675)* | 0.0080 *(0.0030)* | 0.7390 |
| Western Cape | | 2.4335 *(1.5815)* | -0.3897 *(0.2613)* | | |
| Eastern Cape | | — | — | | |
| Northern Cape | | -0.3264 *(1.5527)* | -0.0716 *(0.1925)* | | |
| Free State | | -0.8136 *(0.8701)* | -0.0359 *(0.1201)* | | |
| KwaZulu Natal | | -0.4219 *(0.4999)* | -0.0535 *(0.0727)* | | |
| South Africa North West | | -0.2773 *(0.6361)* | -0.0938 *(0.1021)* | | |
| Gauteng | | 1.9846 *(0.8332)* | -0.2182 *(0.1044)* | | |
| Mpumalanga | | -0.0671 *(0.6554)* | -0.0319 *(0.1004)* | | |
| Northern Province | | 0.1569 *(0.7092)* | -0.1064 *(0.0954)* | | |

# Appendix 7

# Regression Coefficients Determining the Sizes and Explaining Variations in Derived National and Sub-national Values of γ

## 6.12 SAHEL WEST AFRICA

| Country / Region | $\gamma_i$: $\lambda_h$ | $\gamma_i$: $\lambda_{h.i}$ | $\gamma_i$: $\lambda_{h.t.i}$ | $R^2$ |
|---|---|---|---|---|
| **Senegal** | **0.5059 *(0.0252)*** | | **-0.0114 *(0.0043)*** | **0.6208** |
| *Sub-national regions* | 0.5725 *(0.0551)* | | -0.0280 *(0.0095)* | 0.5691 |
| Senegal West | | — | | |
| Senegal Central | | -0.0947 *(0.0666)* | | |
| Senegal North East | | -0.0391 *(0.0831)* | | |
| Senegal South | | -0.1651 *(0.0848)* | | |
| **Mali** | **0.5129 *(0.0239)*** | | **0.0073 *(0.0042)*** | **0.7025** |
| *Sub-national regions* | 0.5111 *(0.0430)* | | 0.0093 *(0.0075)* | 0.7358 |
| Kayes/Koulikoro | | — | — | |
| Sikasso/Segou | | 0.0819 *(0.0594)* | -0.0064 *(0.0103)* | |
| Mopti/Gao/Timbouctou | | -0.1292 *(0.0624)* | -0.0047 *(0.0108)* | |
| Bamako | | -0.0153 *(0.1118)* | 0.0206 *(0.0193)* | |
| **Burkina Faso** | **0.5227 *(0.0362)*** | | **0.0025 *(0.0055)*** | **0.7186** |
| *Sub-national regions* | 0.5379 *(0.0661)* | | 0.0013 *(0.0100)* | 0.7315 |
| Ouagadougou | | 0.1857 *(0.1613)* | -0.0197 *(0.0275)* | |
| Burkina North | | -0.1005 *(0.1095)* | 0.0135 *(0.0167)* | |
| Burkina East | | 0.0348 *(0.0981)* | 0.0044 *(0.0147)* | |
| Burkina West | | -0.0860 *(0.1019)* | -0.0062 *(0.0157)* | |
| Burkina Central/South | | — | — | |
| **Niger** | **0.7314 *(0.0234)*** | | **0.0149 *(0.0039)*** | **0.6105** |
| *Sub-national regions* | 0.7637 *(0.0473)* | | 0.0159 *(0.0077)* | 0.6589 |
| Niamey | | 0.0736 *(0.1485)* | -0.0362 *(0.0250)* | |
| Dosso | | -0.3402 *(0.0843)* | -0.0103 *(0.0141)* | |
| Maradi | | 0.0730 *(0.0660)* | 0.0058 *(0.0109)* | |
| Tahoua/Agadez | | 0.0744 *(0.0684)* | 0.0027 *(0.0114)* | |
| Tillaberi | | -0.2541 *(0.0807)* | -0.0048 *(0.0131)* | |
| Zinda/Diffa | | — | — | |

## 6.13 COASTAL WEST AFRICA

| **Country** | $\gamma_i$ | | | |
|---|---|---|---|---|
| **Region** | $\lambda_h$ | $\lambda_{h.i}$ | $\lambda_{h.t.i}$ | $R^2$ |
| **Guinea** | **0.4709 *(0.0824)*** | | **-0.0026 *(0.0101)*** | **0.7474** |
| *Sub-national regions* | 0.5927 *(0.1742)* | | -0.0181 *(0.0213)* | 0.7663 |
| Lower Guinea | | — | — | |
| Central Guinea | | -0.2283 *(0.2453)* | 0.0308 *(0.0305)* | |
| Upper Guinea | | -0.4480 *(0.2560)* | 0.0412 *(0.0311)* | |
| Forest Guinea | | -0.0926 *(0.2365)* | 0.0210 *(0.0290)* | |
| Conakry | | 0.4512 *(0.3336)* | -0.0481 *(0.0406)* | |
| **Liberia** | **0.6296 *(0.0864)*** | | **0.0083 *(0.0130)*** | **0.8626** |
| *Sub-national regions* | 0.8765 *(0.5066)* | | 0.0430 *(0.0749)* | 0.8689 |
| Sinoe | | — | — | |
| Grand Gedeh | | -0.3211 *(0.5894)* | -0.0328 *(0.0868)* | |
| Montserrado | | 0.0061 *(0.5313)* | -0.0147 *(0.0791)* | |
| Rest of Liberia | | -0.3717 *(0.5189)* | -0.0475 *(0.0767)* | |
| **Côte d'Ivoire** | **0.3582 *(0.0619)*** | | **0.0329 *(0.0123)*** | **0.7039** |
| *Sub-national regions* | 0.3419 *(0.2342)* | | 0.0531 *(0.0482)* | 0.7280 |
| CI Centre | | — | — | |
| CI Centre North | | 0.0958 *(0.3519)* | 0.0063 *(0.0725)* | |
| CI North East | | -0.4197 *(0.3711)* | 0.0400 *(0.0750)* | |
| CI Centre East | | 0.0177 *(0.3738)* | -0.0463 *(0.0780)* | |
| CI South | | -0.0532 *(0.2630)* | -0.0210 *(0.0537)* | |
| CI South West | | 0.3209 *(0.3481)* | -0.0637 *(0.0691)* | |
| CI Centre West | | 0.0333 *(0.2694)* | -0.0047 *(0.0554)* | |
| CI West | | 0.2852 *(0.2951)* | -0.0524 *(0.0588)* | |
| CI West | | -0.4477 *(0.3755)* | 0.0294 *(0.0721)* | |
| CI North | | 0.3305 *(0.3454)* | -0.0850 *(0.0705)* | |
| **Ghana** | **0.3904 *(0.0398)*** | | **-0.0019 *(0.0067)*** | **0.5396** |
| *Sub-national regions* | 0.5298 *(0.1020)* | | 0.0052 *(0.0175)* | 0.5768 |
| Ghana Western | | -0.0894 *(0.1598)* | 0.0232 *(0.0269)* | |
| Ghana Central | | 0.1978 *(0.1546)* | 0.0070 *(0.0261)* | |
| Greater Accra | | -0.1453 *(0.1839)* | -0.0378 *(0.0314)* | |
| Volta | | -0.1051 *(0.1488)* | -0.0169 *(0.0256)* | |
| Ghana Eastern | | -0.4932 *(0.1670)* | -0.0057 *(0.0281)* | |
| Ashanti | | — | — | |
| Brong-Ahafo | | -0.2268 *(0.1610)* | 0.0023 *(0.0283)* | |
| Ghana Northern | | -0.1394 *(0.1716)* | -0.0231 *(0.0296)* | |
| Ghana Upper West | | -0.3093 *(0.2525)* | -0.0181 *(0.0439)* | |
| Ghana Upper East | | -0.4002 *(0.2197)* | 0.0138 *(0.0374)* | |

| Country / Region | $\gamma_i$: $\lambda_h$ | $\lambda_{h.i}$ | $\lambda_{h.t.i}$ | $R^2$ |
|---|---|---|---|---|
| **Togo** | **0.1835 *(0.0408)*** | | **0.0007 *(0.0061)*** | **0.6533** |
| *Sub-national regions* | 0.2465 *(0.1197)* | | -0.0215 *(0.0179)* | 0.6684 |
| Maritime | | -0.0509 *(0.1397)* | 0.0158 *(0.0209)* | |
| des Plateaux | | -0.1125 *(0.1492)* | 0.0136 *(0.0221)* | |
| Togo Centrale | | — | — | |
| de la Kara | | -0.1381 *(0.1555)* | 0.0362 *(0.0234)* | |
| des Savanes | | 0.0440 *(0.1542)* | 0.0419 *(0.0230)* | |
| **Benin** | **0.2029 *(0.0645)*** | | **0.0290 *(0.0111)*** | **0.6597** |
| *Sub-national regions* | 0.4532 *(0.1562)* | | -0.0031 *(0.0267)* | 0.6851 |
| Atacora | | -0.3305 *(0.2163)* | 0.0084 *(0.0373)* | |
| Atlantique | | -0.0511 *(0.2292)* | 0.0471 *(0.0390)* | |
| Borgou | | — | — | |
| Mono | | -0.5373 *(0.2292)* | 0.0509 *(0.0395)* | |
| Oueme | | 0.2810 *(0.2303)* | 0.0101 *(0.0399)* | |
| Zou | | -0.7130 *(0.2244)* | 0.0734 *(0.0379)* | |
| **Nigeria** | **0.6110 *(0.0298)*** | | **0.0043 *(0.0049)*** | **0.6479** |
| *Sub-national regions* | 0.6930 *(0.0672)* | | -0.0168 *(0.0101)* | 0.7146 |
| Nigeria North East | | — | — | |
| Nigeria North West | | 0.1739 *(0.0884)* | 0.0119 *(0.0138)* | |
| Nigeria South East | | 0.0071 *(0.0990)* | 0.0248 *(0.0157)* | |
| Nigeria South West | | -0.3480 *(0.0977)* | 0.0271 *(0.0158)* | |
| Nigeria Central | | -0.3494 *(0.0998)* | 0.0479 *(0.0162)* | |

## 6.14 MIDDLE AFRICA

| Country / Region | $\gamma_i$: $\lambda_h$ | $\gamma_i$: $\lambda_{h.i}$ | $\gamma_i$: $\lambda_{h.t.i}$ | $R^2$ |
|---|---|---|---|---|
| **Cameroon** | **0.5232 *(0.0530)*** | | **-0.0105 *(0.0084)*** | **0.6357** |
| *Sub-national regions* | 0.4911 *(0.0686)* | | -0.0039 *(0.0111)* | 0.6927 |
| North/Adamawa | | — | — | |
| Central/South/East | | 0.1268 *(0.1415)* | -0.0292 *(0.0217)* | |
| West/Littoral | | 0.0461 *(0.1707)* | 0.0009 *(0.0273)* | |
| Northwest/Southwest | | 0.0290 *(0.1783)* | -0.0076 *(0.0276)* | |
| **Central African Republic** | **0.3273 *(0.0630)*** | | **0.0252 *(0.0094)*** | **0.6358** |
| *Sub-national regions* | 0.0738 *(0.1543)* | | 0.0062 *(0.0307)* | 0.7659 |
| CAR Health Region I | | 0.4949 *(0.2247)* | -0.0607 *(0.0431)* | |
| CAR Health Region II | | 0.1370 *(0.2175)* | -0.0134 *(0.0431)* | |
| CAR Health Region III | | — | — | |
| CAR Health Region IV | | 0.3549 *(0.3037)* | 0.0112 *(0.0596)* | |
| CAR Health Region V | | 0.6874 *(0.2872)* | -0.0082 *(0.0573)* | |
| Bangui | | 0.4139 *(0.2501)* | 0.0231 *(0.0485)* | |
| **Chad** | **0.3609 *(0.0739)*** | | **-0.0064 *(0.0143)*** | **0.7426** |
| *Sub-national regions* | 0.4621 *(0.2911)* | | 0.0632 *(0.0482)* | 0.6755 |
| Batha | | — | — | |
| Borkou-Ennedi-Tibesti | | -0.6290 *(0.8692)* | 0.0838 *(0.1257)* | |
| Biltine | | -0.5184 *(0.4928)* | 0.0552 *(0.0893)* | |
| Chari-Baguirmi | | -0.1990 *(0.3411)* | -0.0799 *(0.0556)* | |
| Guéra | | -0.1971 *(0.3854)* | -0.0150 *(0.0638)* | |
| Kanem | | -0.1043 *(0.3716)* | -0.0413 *(0.0594)* | |
| Lac | | 0.7760 *(0.5485)* | -0.1148 *(0.0788)* | |
| Logone Occidental | | -0.2532 *(0.3881)* | 0.0642 *(0.0650)* | |
| Logone Oriental | | -0.1172 *(0.3577)* | -0.0444 *(0.0574)* | |
| Mayo-Kébbi | | -0.0022 *(0.3701)* | -0.0395 *(0.0582)* | |
| Moyen Chari | | -0.3276 *(0.3747)* | -0.0129 *(0.0581)* | |
| Ouaddaï | | -0.4083 *(0.3419)* | -0.0503 *(0.0560)* | |
| Salamat | | 0.1980 *(0.4177)* | -0.1296 *(0.0671)* | |
| Tandjilé | | -0.0926 *(0.3637)* | -0.0280 *(0.0570)* | |
| N'Djamena | | 0.4114 *(0.3741)* | -0.0792 *(0.0585)* | |

## 6.15 EASTERN AFRICA

| Country / Region | $\gamma_i$: $\lambda_h$ | $\lambda_{h.i}$ | $\lambda_{h.t.i}$ | $\lambda_{h.T.i}$ | $R^2$ |
|---|---|---|---|---|---|
| **Uganda** | **0.6613 *(0.0340)*** | | **0.0160 *(0.0065)*** | | **0.7493** |
| *Sub-national regions* | 0.6285 *(0.0653)* | | 0.0298 *(0.0130)* | | 0.7628 |
| Uganda Central | | — | — | | |
| Uganda Eastern | | 0.0791 *(0.0914)* | -0.0416 *(0.0179)* | | |
| Uganda Northern | | -0.0855 *(0.1084)* | 0.0143 *(0.0212)* | | |
| Uganda Western | | 0.0761 *(0.0920)* | -0.0114 *(0.0179)* | | |
| **Rwanda** | **0.1505 *(0.0446)*** | | **0.0120 *(0.0112)*** | | **0.6735** |
| **Burundi** | **0.2182 *(0.0862)*** | | **-0.0298 *(0.0137)*** | | **0.6240** |
| **Kenya** | **0.5318 *(0.0469)*** | | **0.0126 *(0.0069)*** | **-0.0017 *(0.0010)*** | **0.6631** |
| *Sub-national regions* | 0.0399 *(0.1379)* | | 0.0111 *(0.0204)* | 0.0053 *(0.0031)* | 0.7644 |
| Nairobi | | 0.3898 *(0.2730)* | -0.0615 *(0.0443)* | -0.0069 *(0.0063)* | |
| Kenya Central | | 0.4586 *(0.2657)* | -0.0507 *(0.0381)* | -0.0156 *(0.0062)* | |
| Kenya Coast | | 0.5471 *(0.2114)* | 0.0333 *(0.0287)* | -0.0087 *(0.0045)* | |
| Kenya Eastern | | — | — | — | |
| Nyanza | | 0.7285 *(0.1600)* | -0.0059 *(0.0241)* | -0.0073 *(0.0035)* | |
| Rift Valley | | 0.1582 *(0.1968)* | -0.0150 *(0.0285)* | -0.0023 *(0.0042)* | |
| Kenya Western | | 0.6992 *(0.1712)* | 0.0107 *(0.0251)* | -0.0109 *(0.0038)* | |
| **Tanzania** | **0.5097 *(0.0339)*** | | **0.0003 *(0.0058)*** | | **0.7415** |
| *Sub-national regions* | 0.4627 *(0.0583)* | | 0.0038 *(0.0112)* | 0.0020 *(0.0011)* | 0.7658 |
| Tanzania Coastal | | 0.1485 *(0.0930)* | -0.0280 *(0.0165)* | | |
| Tz Northern Highlands | | 0.2888 *(0.1698)* | -0.0642 *(0.0285)* | | |
| Lake | | — | — | | |
| Tanzania Central | | -0.0133 *(0.1120)* | -0.0153 *(0.0194)* | | |
| Tz Southern Highlands | | -0.1156 *(0.1096)* | -0.0253 *(0.0185)* | | |
| Tanzania South | | -0.0746 *(0.1192)* | -0.0097 *(0.0208)* | | |
| **Ethiopia** | **0.0288 *(0.0675)*** | | **0.0141 *(0.0077)*** | | **0.7679** |
| *Sub-national regions* | 0.1295 *(0.0616)* | | 0.0090 *(0.0157)* | | 0.7802 |
| Tigray | | -0.0642 *(0.1420)* | -0.0474 *(0.0363)* | | |
| Affar | | 0.1751 *(0.2278)* | -0.0127 *(0.0585)* | | |
| Amhara | | 0.0255 *(0.0879)* | -0.0072 *(0.0224)* | | |
| Oromiya | | 0.0068 *(0.0778)* | 0.0217 *(0.0197)* | | |
| Somali | | 0.0187 *(0.2721)* | 0.0875 *(0.0699)* | | |
| Ben-Gumz | | -0.2983 *(0.2882)* | 0.0065 *(0.0739)* | | |
| SNNP | | — | — | | |
| Gambela | | 0.1647 *(0.5200)* | 0.0012 *(0.1353)* | | |
| Harari | | 0.2384 *(0.6535)* | -0.0471 *(0.1628)* | | |
| Addis | | 0.8505 *(0.3691)* | -0.0641 *(0.0919)* | | |
| Dire Dawa | | 0.2992 *(0.5476)* | -0.0332 *(0.1381)* | | |

## 6.16 SOUTHERN AFRICA

| Country / Region | $\gamma_i$ | | | | $R^2$ |
|---|---|---|---|---|---|
| | $\lambda_h$ | $\lambda_{h.i}$ | $\lambda_{h.t.i}$ | $\lambda_{h.T.i}$ | |
| **Zambia** | **0.7361 *(0.0372)*** | | **0.0255 *(0.0068)*** | | **0.6663** |
| *Sub-national regions* | 0.6896 *(0.1126)* | | -0.0017 *(0.0278)* | 0.0012 *(0.0036)* | 0.7101 |
| Zambia Central | | -0.1838 *(0.1847)* | -0.0267 *(0.0414)* | 0.0120 *(0.0057)* | |
| Copperbelt | | 0.3467 *(0.1485)* | 0.0334 *(0.0348)* | -0.0063 *(0.0047)* | |
| Zambia Eastern | | 0.0330 *(0.1483)* | 0.0298 *(0.0365)* | 0.0007 *(0.0048)* | |
| Luapula | | 0.1389 *(0.1700)* | 0.0111 *(0.0415)* | -0.0012 *(0.0053)* | |
| Lusaka | | -0.0919 *(0.1659)* | 0.0434 *(0.0392)* | -0.0002 *(0.0050)* | |
| Zambia Northern | | — | — | — | |
| Zambia North-Western | | -0.5970 *(0.2824)* | -0.0390 *(0.0674)* | 0.0099 *(0.0086)* | |
| Zambia Southern | | 0.1458 *(0.1738)* | 0.0471 *(0.0388)* | -0.0014 *(0.0052)* | |
| Zambia Western | | -0.2985 *(0.1925)* | 0.0323 *(0.0445)* | 0.0002 *(0.0059)* | |
| **Malawi** | **0.5053 *(0.0427)*** | | **0.0204 *(0.0106)*** | | **0.7835** |
| *Sub-national regions* | 0.3596 *(0.1447)* | | 0.0452 *(0.0357)* | | 0.8040 |
| Malawi North | | — | — | | |
| Malawi Central | | 0.0994 *(0.1570)* | -0.0112 *(0.0387)* | | |
| Malawi South | | 0.2525 *(0.1593)* | -0.0453 *(0.0394)* | | |
| **Zimbabwe** | **0.6969 *(0.0567)*** | | **-0.0067 *(0.0086)*** | | **0.5991** |
| *Sub-national regions* | 0.8847 *(0.1306)* | | -0.0437 *(0.0184)* | | 0.6270 |
| Manicaland | | — | — | | |
| Mashonaland Central | | -0.2863 *(0.2183)* | 0.0596 *(0.0344)* | | |
| Mashonaland East | | -0.3350 *(0.1973)* | 0.0615 *(0.0294)* | | |
| Mashonaland West | | -0.2660 *(0.2169)* | 0.0676 *(0.0326)* | | |
| Matabeleland North | | -0.2415 *(0.2958)* | 0.0728 *(0.0471)* | | |
| Matabeleland South | | 0.5466 *(0.3648)* | 0.0769 *(0.0551)* | | |
| Zimbabwe Midlands | | -0.1347 *(0.2052)* | 0.0140 *(0.0298)* | | |
| Masvingo | | -0.3274 *(0.1988)* | 0.0407 *(0.0318)* | | |
| Harare Chitungwiza | | -0.0226 *(0.2794)* | 0.0127 *(0.0361)* | | |
| Bulawayo | | 0.1869 *(0.4050)* | 0.0099 *(0.0531)* | | |
| **Mozambique** | **0.6246 *(0.0659)*** | | **-0.0366 *(0.0100)*** | | **0.6953** |
| *Sub-national regions* | 0.7257 *(0.3119)* | | -0.0302 *(0.0448)* | | 0.7485 |
| Niassa | | -0.7474 *(0.4083)* | 0.0487 *(0.0603)* | | |
| Cabo Delgado | | 0.3507 *(0.5070)* | -0.0495 *(0.0687)* | | |
| Nampula | | 0.4796 *(0.3428)* | -0.0802 *(0.0494)* | | |
| Zambezia | | -0.4341 *(0.3529)* | 0.0323 *(0.0517)* | | |
| Tete | | -0.5754 *(0.3843)* | 0.0424 *(0.0578)* | | |
| Manica | | — | — | | |
| Sofala | | -0.0451 *(0.3426)* | -0.0462 *(0.0501)* | | |
| Inhambane | | -0.0211 *(0.4054)* | 0.0222 *(0.0591)* | | |
| Gaza | | -0.5819 *(0.3891)* | 0.1068 *(0.0546)* | | |
| Maputo | | -0.1375 *(0.4487)* | 0.0227 *(0.0661)* | | |
| Cidade de Maputo | | 0.3540 *(0.5198)* | -0.0972 *(0.0748)* | | |

| Country / Region | $\gamma_i$: $\lambda_h$ | $\lambda_{h.i}$ | $\lambda_{h.t.i}$ | $\lambda_{h.T.i}$ | $R^2$ |
|---|---|---|---|---|---|
| **Namibia** | **0.3678** ***(0.0896)*** | | **-0.0449** ***(0.0220)*** | | **0.7057** |
| *Sub-national regions* | 0.2728 *(0.1498)* | | -0.0724 *(0.0366)* | | 0.7309 |
| Namibia Northwest | | — | — | | |
| Namibia Northeast | | 0.0461 *(0.2199)* | 0.0739 *(0.0537)* | | |
| Namibia Central | | -0.2316 *(0.3285)* | 0.0415 *(0.0798)* | | |
| Namibia South | | 0.4711 *(0.2474)* | 0.0327 *(0.0609)* | | |
| **South Africa** | **0.7262** ***(0.1688)*** | | **0.0025** ***(0.0237)*** | | **0.6773** |
| *Sub-national regions* | 1.0186 *(0.3368)* | | 0.0227 *(0.0539)* | | 0.7390 |
| Western Cape | | 2.7812 *(1.8053)* | -0.0923 *(0.2826)* | | |
| Eastern Cape | | — | — | | |
| Northern Cape | | 0.6702 *(1.4101)* | -0.2001 *(0.1851)* | | |
| Free State | | 0.1133 *(0.7547)* | -0.1077 *(0.1100)* | | |
| KwaZulu Natal | | -0.8373 *(0.4575)* | 0.0266 *(0.0678)* | | |
| South Africa North West | | -1.2566 *(0.6490)* | -0.0493 *(0.1130)* | | |
| Gauteng | | 2.4681 *(0.8882)* | -0.2576 *(0.1091)* | | |
| Mpumalanga | | -0.7630 *(0.6267)* | -0.0118 *(0.1018)* | | |
| Northern Province | | -0.5529 *(0.7312)* | 0.0145 *(0.0952)* | | |

# Appendix 8

# Fitted National Life Tables for Childhood and Early Adulthood, 1975 – 1995

## Senegal

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.36737 | 1.00000 | 0.33289 | 1.00000 | 0.30165 | 1.00000 | 0.27333 | 1.00000 | 0.24768 | 1.00000 |
| 0.0833 | 0.21225 | 0.96985 | 0.18721 | 0.97264 | 0.16512 | 0.97517 | 0.14564 | 0.97748 | 0.12845 | 0.97957 |
| 0.25 | 0.12428 | 0.93613 | 0.10676 | 0.94276 | 0.09172 | 0.94870 | 0.07880 | 0.95404 | 0.06769 | 0.95882 |
| 0.5 | 0.15383 | 0.90749 | 0.12235 | 0.91793 | 0.09730 | 0.92719 | 0.07739 | 0.93543 | 0.06155 | 0.94273 |
| 0.75 | 0.11591 | 0.87325 | 0.09091 | 0.89027 | 0.07130 | 0.90491 | 0.05592 | 0.91750 | 0.04386 | 0.92834 |
| 1 | 0.09323 | 0.84831 | 0.07234 | 0.87026 | 0.05613 | 0.88892 | 0.04356 | 0.90476 | 0.03380 | 0.91821 |
| 1.25 | 0.06820 | 0.82876 | 0.05211 | 0.85467 | 0.03982 | 0.87654 | 0.03043 | 0.89496 | 0.02325 | 0.91049 |
| 2 | 0.02470 | 0.78743 | 0.01960 | 0.82190 | 0.01555 | 0.85074 | 0.01234 | 0.87477 | 0.00979 | 0.89475 |
| 3 | 0.01909 | 0.76822 | 0.01495 | 0.80595 | 0.01171 | 0.83762 | 0.00918 | 0.86405 | 0.00719 | 0.88603 |
| 4 | 0.01495 | 0.75370 | 0.01157 | 0.79399 | 0.00896 | 0.82786 | 0.00694 | 0.85615 | 0.00537 | 0.87968 |
| 5 | 0.00873 | 0.74251 | 0.00658 | 0.78485 | 0.00496 | 0.82048 | 0.00374 | 0.85024 | 0.00282 | 0.87497 |
| 10 | 0.00501 | 0.71080 | 0.00367 | 0.75945 | 0.00269 | 0.80038 | 0.00198 | 0.83449 | 0.00145 | 0.86273 |
| 15 | 0.00601 | 0.69323 | 0.00445 | 0.74564 | 0.00329 | 0.78967 | 0.00244 | 0.82629 | 0.00181 | 0.85650 |
| 20 | 0.00793 | 0.67270 | 0.00595 | 0.72923 | 0.00446 | 0.77677 | 0.00335 | 0.81627 | 0.00251 | 0.84881 |
| $_1q_0$ = | | 0.15169 | | 0.12974 | | 0.11108 | | 0.09524 | | 0.08179 |
| $_4q_1$ = | | 0.12472 | | 0.09814 | | 0.07700 | | 0.06027 | | 0.04709 |

## Mali

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.70768 | 1.00000 | 0.63461 | 1.00000 | 0.56909 | 1.00000 | 0.51033 | 1.00000 | 0.45764 | 1.00000 |
| 0.0833 | 0.37675 | 0.94272 | 0.33470 | 0.94848 | 0.29735 | 0.95367 | 0.26417 | 0.95836 | 0.23469 | 0.96258 |
| 0.25 | 0.20367 | 0.88532 | 0.17929 | 0.89700 | 0.15784 | 0.90755 | 0.13895 | 0.91707 | 0.12232 | 0.92565 |
| 0.5 | 0.19821 | 0.84136 | 0.17970 | 0.85768 | 0.16291 | 0.87244 | 0.14769 | 0.88576 | 0.13389 | 0.89777 |
| 0.75 | 0.14318 | 0.80068 | 0.12918 | 0.81999 | 0.11655 | 0.83761 | 0.10515 | 0.85365 | 0.09487 | 0.86821 |
| 1 | 0.11148 | 0.77252 | 0.10020 | 0.79393 | 0.09007 | 0.81356 | 0.08096 | 0.83150 | 0.07277 | 0.84786 |
| 1.25 | 0.07784 | 0.75129 | 0.06959 | 0.77429 | 0.06222 | 0.79544 | 0.05563 | 0.81484 | 0.04974 | 0.83257 |
| 2 | 0.03181 | 0.70868 | 0.02724 | 0.73491 | 0.02333 | 0.75917 | 0.01998 | 0.78153 | 0.01711 | 0.80208 |
| 3 | 0.02365 | 0.68649 | 0.02017 | 0.71515 | 0.01720 | 0.74166 | 0.01466 | 0.76607 | 0.01250 | 0.78848 |
| 4 | 0.01787 | 0.67044 | 0.01517 | 0.70088 | 0.01288 | 0.72902 | 0.01094 | 0.75492 | 0.00929 | 0.77868 |
| 5 | 0.00962 | 0.65857 | 0.00810 | 0.69032 | 0.00681 | 0.71969 | 0.00573 | 0.74671 | 0.00482 | 0.77148 |
| 10 | 0.00508 | 0.62762 | 0.00423 | 0.66293 | 0.00353 | 0.69558 | 0.00294 | 0.72561 | 0.00245 | 0.75310 |
| 15 | 0.00627 | 0.61188 | 0.00525 | 0.64904 | 0.00439 | 0.68342 | 0.00367 | 0.71502 | 0.00306 | 0.74393 |
| 20 | 0.00861 | 0.59298 | 0.00724 | 0.63224 | 0.00608 | 0.66859 | 0.00511 | 0.70203 | 0.00429 | 0.73261 |
| $_1q_0$ = | | 0.22748 | | 0.20607 | | 0.18644 | | 0.16850 | | 0.15214 |
| $_4q_1$ = | | 0.14751 | | 0.13050 | | 0.11538 | | 0.10197 | | 0.09009 |

## Burkina Faso

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.62428 | 1.00000 | 0.54485 | 1.00000 | 0.47553 | 1.00000 | 0.41503 | 1.00000 | 0.36223 | 1.00000 |
| 0.0833 | 0.29712 | 0.94930 | 0.26730 | 0.95560 | 0.24047 | 0.96114 | 0.21633 | 0.96600 | 0.19462 | 0.97026 |
| 0.25 | 0.14399 | 0.90342 | 0.13342 | 0.91396 | 0.12363 | 0.92338 | 0.11456 | 0.93179 | 0.10615 | 0.93929 |
| 0.5 | 0.13661 | 0.87148 | 0.13108 | 0.88397 | 0.12577 | 0.89527 | 0.12068 | 0.90548 | 0.11580 | 0.91469 |
| 0.75 | 0.09314 | 0.84221 | 0.09078 | 0.85547 | 0.08847 | 0.86756 | 0.08623 | 0.87857 | 0.08404 | 0.88859 |
| 1 | 0.06936 | 0.82283 | 0.06842 | 0.83628 | 0.06749 | 0.84858 | 0.06658 | 0.85983 | 0.06567 | 0.87012 |
| 1.25 | 0.04543 | 0.80868 | 0.04560 | 0.82209 | 0.04576 | 0.83438 | 0.04593 | 0.84564 | 0.04609 | 0.85595 |
| 2 | 0.01617 | 0.78159 | 0.01638 | 0.79445 | 0.01659 | 0.80623 | 0.01681 | 0.81700 | 0.01703 | 0.82686 |
| 3 | 0.01141 | 0.76905 | 0.01172 | 0.78155 | 0.01205 | 0.79296 | 0.01238 | 0.80338 | 0.01272 | 0.81289 |
| 4 | 0.00820 | 0.76033 | 0.00854 | 0.77244 | 0.00889 | 0.78346 | 0.00926 | 0.79350 | 0.00965 | 0.80262 |
| 5 | 0.00396 | 0.75413 | 0.00424 | 0.76587 | 0.00455 | 0.77653 | 0.00489 | 0.78618 | 0.00524 | 0.79491 |
| 10 | 0.00186 | 0.73936 | 0.00206 | 0.74979 | 0.00228 | 0.75904 | 0.00253 | 0.76720 | 0.00279 | 0.77434 |
| 15 | 0.00239 | 0.73250 | 0.00262 | 0.74210 | 0.00287 | 0.75043 | 0.00314 | 0.75757 | 0.00344 | 0.76359 |
| 20 | 0.00347 | 0.72380 | 0.00374 | 0.73245 | 0.00404 | 0.73975 | 0.00436 | 0.74577 | 0.00470 | 0.75057 |
| $_1q_0$ = | | 0.17717 | | 0.16372 | | 0.15142 | | 0.14017 | | 0.12988 |
| $_4q_1$ = | | 0.08350 | | 0.08419 | | 0.08491 | | 0.08566 | | 0.08643 |

## Niger

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.42250 | 1.00000 | 0.40219 | 1.00000 | 0.38286 | 1.00000 | 0.36446 | 1.00000 | 0.34694 | 1.00000 |
| 0.0833 | 0.26807 | 0.96540 | 0.25039 | 0.96704 | 0.23389 | 0.96860 | 0.21847 | 0.97008 | 0.20407 | 0.97150 |
| 0.25 | 0.17197 | 0.92321 | 0.15770 | 0.92750 | 0.14460 | 0.93156 | 0.13260 | 0.93539 | 0.12159 | 0.93901 |
| 0.5 | 0.21969 | 0.88435 | 0.21403 | 0.89165 | 0.20852 | 0.89848 | 0.20315 | 0.90489 | 0.19791 | 0.91089 |
| 0.75 | 0.17373 | 0.83708 | 0.16761 | 0.84518 | 0.16170 | 0.85283 | 0.15601 | 0.86007 | 0.15051 | 0.86691 |
| 1 | 0.14502 | 0.80150 | 0.13886 | 0.81049 | 0.13297 | 0.81904 | 0.12732 | 0.82717 | 0.12192 | 0.83490 |
| 1.25 | 0.11190 | 0.77296 | 0.10600 | 0.78284 | 0.10041 | 0.79226 | 0.09512 | 0.80125 | 0.09010 | 0.80983 |
| 2 | 0.04503 | 0.71070 | 0.03905 | 0.72298 | 0.03387 | 0.73476 | 0.02937 | 0.74606 | 0.02547 | 0.75689 |
| 3 | 0.03637 | 0.67940 | 0.03126 | 0.69528 | 0.02687 | 0.71029 | 0.02309 | 0.72447 | 0.01985 | 0.73786 |
| 4 | 0.02970 | 0.65513 | 0.02531 | 0.67389 | 0.02158 | 0.69146 | 0.01839 | 0.70793 | 0.01567 | 0.72336 |
| 5 | 0.01900 | 0.63596 | 0.01590 | 0.65704 | 0.01330 | 0.67670 | 0.01113 | 0.69503 | 0.00931 | 0.71211 |
| 10 | 0.01198 | 0.57827 | 0.00984 | 0.60680 | 0.00807 | 0.63314 | 0.00663 | 0.65740 | 0.00544 | 0.67971 |
| 15 | 0.01396 | 0.54463 | 0.01153 | 0.57768 | 0.00952 | 0.60809 | 0.00786 | 0.63597 | 0.00649 | 0.66147 |
| 20 | 0.01754 | 0.50791 | 0.01463 | 0.54532 | 0.01220 | 0.57982 | 0.01017 | 0.61145 | 0.00848 | 0.64034 |
| $_1q_0$ = | | 0.19850 | | 0.18951 | | 0.18096 | | 0.17283 | | 0.16510 |
| $_4q_1$ = | | 0.20653 | | 0.18933 | | 0.17379 | | 0.15975 | | 0.14707 |

## Guinea

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.71951 | 1.00000 | 0.63717 | 1.00000 | 0.56424 | 1.00000 | 0.49967 | 1.00000 | 0.44248 | 1.00000 |
| 0.0833 | 0.38870 | 0.94179 | 0.33579 | 0.94828 | 0.29008 | 0.95406 | 0.25060 | 0.95921 | 0.21649 | 0.96379 |
| 0.25 | 0.21315 | 0.88269 | 0.17974 | 0.89665 | 0.15157 | 0.90902 | 0.12781 | 0.91997 | 0.10778 | 0.92964 |
| 0.5 | 0.22195 | 0.83687 | 0.18137 | 0.85725 | 0.14821 | 0.87522 | 0.12111 | 0.89103 | 0.09896 | 0.90492 |
| 0.75 | 0.16154 | 0.79169 | 0.13033 | 0.81924 | 0.10515 | 0.84338 | 0.08483 | 0.86446 | 0.06844 | 0.88280 |
| 1 | 0.12650 | 0.76035 | 0.10106 | 0.79297 | 0.08074 | 0.82150 | 0.06450 | 0.84632 | 0.05153 | 0.86783 |
| 1.25 | 0.08907 | 0.73668 | 0.07016 | 0.77319 | 0.05526 | 0.80508 | 0.04353 | 0.83278 | 0.03429 | 0.85672 |
| 2 | 0.03476 | 0.68906 | 0.02725 | 0.73355 | 0.02136 | 0.77239 | 0.01674 | 0.80603 | 0.01313 | 0.83497 |
| 3 | 0.02602 | 0.66552 | 0.02016 | 0.71383 | 0.01563 | 0.75607 | 0.01211 | 0.79264 | 0.00938 | 0.82408 |
| 4 | 0.01979 | 0.64842 | 0.01516 | 0.69958 | 0.01162 | 0.74435 | 0.00891 | 0.78311 | 0.00682 | 0.81638 |
| 5 | 0.01081 | 0.63572 | 0.00809 | 0.68905 | 0.00605 | 0.73575 | 0.00452 | 0.77616 | 0.00338 | 0.81083 |
| 10 | 0.00579 | 0.60226 | 0.00423 | 0.66174 | 0.00308 | 0.71383 | 0.00225 | 0.75880 | 0.00164 | 0.79723 |
| 15 | 0.00712 | 0.58506 | 0.00524 | 0.64791 | 0.00385 | 0.70291 | 0.00283 | 0.75032 | 0.00208 | 0.79072 |
| 20 | 0.00970 | 0.56460 | 0.00723 | 0.63116 | 0.00538 | 0.68950 | 0.00401 | 0.73977 | 0.00298 | 0.78252 |
| $_1q_0$ = | | 0.23965 | | 0.20703 | | 0.17850 | | 0.15368 | | 0.13217 |
| $_4q_1$ = | | 0.16392 | | 0.13105 | | 0.10438 | | 0.08290 | | 0.06568 |

## Liberia

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.86337 | 1.00000 | 0.74276 | 1.00000 | 0.63900 | 1.00000 | 0.54973 | 1.00000 | 0.47294 | 1.00000 |
| 0.0833 | 0.36313 | 0.93055 | 0.31422 | 0.93996 | 0.27190 | 0.94813 | 0.23528 | 0.95521 | 0.20359 | 0.96135 |
| 0.25 | 0.15598 | 0.87589 | 0.13574 | 0.89199 | 0.11813 | 0.90612 | 0.10280 | 0.91848 | 0.08946 | 0.92927 |
| 0.5 | 0.14181 | 0.84238 | 0.12917 | 0.86223 | 0.11766 | 0.87975 | 0.10717 | 0.89517 | 0.09762 | 0.90872 |
| 0.75 | 0.09071 | 0.81304 | 0.08287 | 0.83483 | 0.07571 | 0.85424 | 0.06917 | 0.87151 | 0.06320 | 0.88681 |
| 1 | 0.06432 | 0.79481 | 0.05890 | 0.81771 | 0.05393 | 0.83823 | 0.04939 | 0.85656 | 0.04522 | 0.87291 |
| 1.25 | 0.03926 | 0.78213 | 0.03607 | 0.80576 | 0.03314 | 0.82700 | 0.03045 | 0.84605 | 0.02798 | 0.86310 |
| 2 | 0.01217 | 0.75943 | 0.01077 | 0.78425 | 0.00954 | 0.80670 | 0.00844 | 0.82695 | 0.00747 | 0.84518 |
| 3 | 0.00810 | 0.75025 | 0.00719 | 0.77584 | 0.00638 | 0.79904 | 0.00567 | 0.82000 | 0.00503 | 0.83888 |
| 4 | 0.00551 | 0.74419 | 0.00490 | 0.77028 | 0.00436 | 0.79396 | 0.00388 | 0.81536 | 0.00346 | 0.83467 |
| 5 | 0.00236 | 0.74011 | 0.00211 | 0.76652 | 0.00189 | 0.79050 | 0.00169 | 0.81220 | 0.00151 | 0.83179 |
| 10 | 0.00098 | 0.73144 | 0.00088 | 0.75848 | 0.00079 | 0.78308 | 0.00071 | 0.80538 | 0.00064 | 0.82553 |
| 15 | 0.00131 | 0.72787 | 0.00118 | 0.75514 | 0.00106 | 0.77997 | 0.00095 | 0.80250 | 0.00085 | 0.82288 |
| 20 | 0.00202 | 0.72312 | 0.00181 | 0.75072 | 0.00162 | 0.77587 | 0.00145 | 0.79870 | 0.00130 | 0.81938 |
| $_1q_0$ = | | 0.20519 | | 0.18229 | | 0.16177 | | 0.14344 | | 0.12709 |
| $_4q_1$ = | | 0.06883 | | 0.06260 | | 0.05694 | | 0.05179 | | 0.04710 |

## Côte d'Ivoire

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.66970 | 1.00000 | 0.56128 | 1.00000 | 0.47041 | 1.00000 | 0.39425 | 1.00000 | 0.33042 | 1.00000 |
| 0.0833 | 0.27248 | 0.94571 | 0.23689 | 0.95430 | 0.20595 | 0.96155 | 0.17906 | 0.96768 | 0.15567 | 0.97284 |
| 0.25 | 0.11331 | 0.90371 | 0.10210 | 0.91735 | 0.09200 | 0.92910 | 0.08290 | 0.93922 | 0.07469 | 0.94792 |
| 0.5 | 0.05992 | 0.87847 | 0.06539 | 0.89423 | 0.07135 | 0.90798 | 0.07785 | 0.91996 | 0.08495 | 0.93038 |
| 0.75 | 0.03768 | 0.86541 | 0.04190 | 0.87973 | 0.04659 | 0.89193 | 0.05181 | 0.90223 | 0.05762 | 0.91083 |
| 1 | 0.02637 | 0.85729 | 0.02975 | 0.87056 | 0.03357 | 0.88160 | 0.03787 | 0.89061 | 0.04273 | 0.89781 |
| 1.25 | 0.01579 | 0.85166 | 0.01820 | 0.86411 | 0.02097 | 0.87423 | 0.02416 | 0.88222 | 0.02783 | 0.88827 |
| 2 | 0.00802 | 0.84163 | 0.00805 | 0.85240 | 0.00808 | 0.86059 | 0.00811 | 0.86638 | 0.00814 | 0.86992 |
| 3 | 0.00525 | 0.83491 | 0.00537 | 0.84556 | 0.00548 | 0.85367 | 0.00560 | 0.85938 | 0.00572 | 0.86286 |
| 4 | 0.00352 | 0.83054 | 0.00366 | 0.84104 | 0.00379 | 0.84900 | 0.00394 | 0.85459 | 0.00409 | 0.85795 |
| 5 | 0.00146 | 0.82762 | 0.00157 | 0.83797 | 0.00169 | 0.84578 | 0.00182 | 0.85123 | 0.00195 | 0.85445 |
| 10 | 0.00059 | 0.82161 | 0.00065 | 0.83143 | 0.00073 | 0.83868 | 0.00082 | 0.84354 | 0.00091 | 0.84614 |
| 15 | 0.00079 | 0.81921 | 0.00087 | 0.82871 | 0.00096 | 0.83562 | 0.00106 | 0.84010 | 0.00117 | 0.84230 |
| 20 | 0.00124 | 0.81597 | 0.00135 | 0.82510 | 0.00146 | 0.83161 | 0.00158 | 0.83565 | 0.00171 | 0.83737 |
| $_1q_0$ = | | 0.14271 | | 0.12944 | | 0.11840 | | 0.10939 | | 0.10219 |
| $_4q_1$ = | | 0.03462 | | 0.03744 | | 0.04062 | | 0.04422 | | 0.04830 |

## Ghana

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.44537 | 1.00000 | 0.38244 | 1.00000 | 0.32841 | 1.00000 | 0.28201 | 1.00000 | 0.24216 | 1.00000 |
| 0.0833 | 0.21366 | 0.96356 | 0.18520 | 0.96863 | 0.16053 | 0.97300 | 0.13915 | 0.97677 | 0.12061 | 0.98002 |
| 0.25 | 0.10435 | 0.92985 | 0.09128 | 0.93919 | 0.07985 | 0.94731 | 0.06985 | 0.95438 | 0.06110 | 0.96052 |
| 0.5 | 0.09114 | 0.90591 | 0.07953 | 0.91800 | 0.06939 | 0.92859 | 0.06055 | 0.93786 | 0.05284 | 0.94596 |
| 0.75 | 0.06239 | 0.88550 | 0.05471 | 0.89992 | 0.04797 | 0.91262 | 0.04206 | 0.92377 | 0.03688 | 0.93354 |
| 1 | 0.04661 | 0.87179 | 0.04102 | 0.88770 | 0.03610 | 0.90174 | 0.03177 | 0.91411 | 0.02796 | 0.92498 |
| 1.25 | 0.03067 | 0.86169 | 0.02714 | 0.87864 | 0.02401 | 0.89364 | 0.02124 | 0.90687 | 0.01880 | 0.91853 |
| 2 | 0.01199 | 0.84210 | 0.01079 | 0.86094 | 0.00970 | 0.87769 | 0.00872 | 0.89254 | 0.00784 | 0.90567 |
| 3 | 0.00849 | 0.83206 | 0.00767 | 0.85170 | 0.00693 | 0.86922 | 0.00626 | 0.88479 | 0.00565 | 0.89860 |
| 4 | 0.00612 | 0.82502 | 0.00556 | 0.84520 | 0.00504 | 0.86322 | 0.00457 | 0.87927 | 0.00414 | 0.89353 |
| 5 | 0.00298 | 0.81998 | 0.00273 | 0.84051 | 0.00250 | 0.85888 | 0.00228 | 0.87526 | 0.00209 | 0.88984 |
| 10 | 0.00142 | 0.80786 | 0.00131 | 0.82913 | 0.00121 | 0.84823 | 0.00112 | 0.86532 | 0.00103 | 0.88058 |
| 15 | 0.00181 | 0.80216 | 0.00167 | 0.82373 | 0.00154 | 0.84312 | 0.00141 | 0.86050 | 0.00130 | 0.87605 |
| 20 | 0.00262 | 0.79494 | 0.00240 | 0.81689 | 0.00220 | 0.83667 | 0.00202 | 0.85444 | 0.00185 | 0.87036 |
| $_1q_0$ = | | 0.12821 | | 0.11230 | | 0.09826 | | 0.08589 | | 0.07502 |
| $_4q_1$ = | | 0.05943 | | 0.05315 | | 0.04753 | | 0.04250 | | 0.03799 |

**Togo**

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.40547 | 1.00000 | 0.37417 | 1.00000 | 0.34528 | 1.00000 | 0.31862 | 1.00000 | 0.29402 | 1.00000 |
| 0.0833 | 0.21309 | 0.96677 | 0.19651 | 0.96930 | 0.18122 | 0.97164 | 0.16713 | 0.97380 | 0.15412 | 0.97580 |
| 0.25 | 0.11375 | 0.93304 | 0.10483 | 0.93806 | 0.09662 | 0.94272 | 0.08905 | 0.94704 | 0.08207 | 0.95105 |
| 0.5 | 0.08422 | 0.90688 | 0.07786 | 0.91380 | 0.07198 | 0.92023 | 0.06654 | 0.92619 | 0.06151 | 0.93173 |
| 0.75 | 0.06043 | 0.88798 | 0.05585 | 0.89618 | 0.05161 | 0.90381 | 0.04770 | 0.91091 | 0.04408 | 0.91751 |
| 1 | 0.04681 | 0.87467 | 0.04325 | 0.88375 | 0.03996 | 0.89223 | 0.03692 | 0.90012 | 0.03411 | 0.90746 |
| 1.25 | 0.03244 | 0.86449 | 0.02997 | 0.87425 | 0.02768 | 0.88336 | 0.02556 | 0.89185 | 0.02361 | 0.89975 |
| 2 | 0.01710 | 0.84371 | 0.01573 | 0.85482 | 0.01447 | 0.86521 | 0.01331 | 0.87491 | 0.01225 | 0.88396 |
| 3 | 0.01264 | 0.82940 | 0.01162 | 0.84148 | 0.01069 | 0.85278 | 0.00983 | 0.86334 | 0.00904 | 0.87320 |
| 4 | 0.00949 | 0.81898 | 0.00873 | 0.83175 | 0.00802 | 0.84371 | 0.00738 | 0.85489 | 0.00678 | 0.86534 |
| 5 | 0.00505 | 0.81125 | 0.00464 | 0.82453 | 0.00426 | 0.83697 | 0.00392 | 0.84861 | 0.00360 | 0.85949 |
| 10 | 0.00263 | 0.79102 | 0.00242 | 0.80562 | 0.00222 | 0.81932 | 0.00204 | 0.83215 | 0.00187 | 0.84416 |
| 15 | 0.00326 | 0.78069 | 0.00300 | 0.79595 | 0.00275 | 0.81028 | 0.00253 | 0.82372 | 0.00232 | 0.83631 |
| 20 | 0.00451 | 0.76806 | 0.00414 | 0.78412 | 0.00381 | 0.79921 | 0.00350 | 0.81338 | 0.00321 | 0.82666 |
| $_1q_0$ = | | 0.12533 | | 0.11625 | | 0.10777 | | 0.09988 | | 0.09254 |
| $_4q_1$ = | | 0.07251 | | 0.06702 | | 0.06193 | | 0.05722 | | 0.05286 |

**Benin**

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.46589 | 1.00000 | 0.42792 | 1.00000 | 0.39305 | 1.00000 | 0.36102 | 1.00000 | 0.33160 | 1.00000 |
| 0.0833 | 0.28791 | 0.96192 | 0.25198 | 0.96496 | 0.22054 | 0.96777 | 0.19301 | 0.97036 | 0.16893 | 0.97274 |
| 0.25 | 0.18002 | 0.91684 | 0.15030 | 0.92527 | 0.12549 | 0.93284 | 0.10477 | 0.93964 | 0.08748 | 0.94574 |
| 0.5 | 0.11543 | 0.87649 | 0.10752 | 0.89115 | 0.10015 | 0.90403 | 0.09329 | 0.91535 | 0.08689 | 0.92528 |
| 0.75 | 0.09005 | 0.85155 | 0.08181 | 0.86751 | 0.07433 | 0.88168 | 0.06753 | 0.89424 | 0.06136 | 0.90539 |
| 1 | 0.07439 | 0.83259 | 0.06630 | 0.84995 | 0.05909 | 0.86544 | 0.05267 | 0.87927 | 0.04694 | 0.89161 |
| 1.25 | 0.05655 | 0.81725 | 0.04903 | 0.83597 | 0.04251 | 0.85275 | 0.03686 | 0.86777 | 0.03196 | 0.88121 |
| 2 | 0.04362 | 0.78331 | 0.03159 | 0.80579 | 0.02288 | 0.82599 | 0.01657 | 0.84411 | 0.01200 | 0.86033 |
| 3 | 0.03479 | 0.74987 | 0.02463 | 0.78073 | 0.01744 | 0.80730 | 0.01235 | 0.83024 | 0.00874 | 0.85007 |
| 4 | 0.02808 | 0.72423 | 0.01946 | 0.76173 | 0.01348 | 0.79335 | 0.00934 | 0.82005 | 0.00647 | 0.84267 |
| 5 | 0.01751 | 0.70418 | 0.01157 | 0.74705 | 0.00765 | 0.78272 | 0.00505 | 0.81242 | 0.00334 | 0.83724 |
| 10 | 0.01075 | 0.64511 | 0.00677 | 0.70504 | 0.00426 | 0.75335 | 0.00268 | 0.79215 | 0.00169 | 0.82337 |
| 15 | 0.01263 | 0.61133 | 0.00808 | 0.68159 | 0.00517 | 0.73748 | 0.00330 | 0.78161 | 0.00211 | 0.81646 |
| 20 | 0.01609 | 0.57391 | 0.01054 | 0.65460 | 0.00691 | 0.71868 | 0.00453 | 0.76880 | 0.00297 | 0.80788 |
| $_1q_0$ = | | 0.16741 | | 0.15005 | | 0.13456 | | 0.12073 | | 0.10839 |
| $_4q_1$ = | | 0.15424 | | 0.12106 | | 0.09558 | | 0.07603 | | 0.06099 |

## Nigeria

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.40575 | 1.00000 | 0.35967 | 1.00000 | 0.31882 | 1.00000 | 0.28261 | 1.00000 | 0.25052 | 1.00000 |
| 0.0833 | 0.21604 | 0.96675 | 0.18989 | 0.97047 | 0.16690 | 0.97378 | 0.14669 | 0.97672 | 0.12893 | 0.97934 |
| 0.25 | 0.11681 | 0.93256 | 0.10182 | 0.94024 | 0.08876 | 0.94706 | 0.07737 | 0.95313 | 0.06744 | 0.95852 |
| 0.5 | 0.12913 | 0.90571 | 0.11431 | 0.91660 | 0.10119 | 0.92628 | 0.08957 | 0.93487 | 0.07929 | 0.94249 |
| 0.75 | 0.09329 | 0.87694 | 0.08222 | 0.89078 | 0.07246 | 0.90314 | 0.06386 | 0.91417 | 0.05629 | 0.92399 |
| 1 | 0.07264 | 0.85672 | 0.06380 | 0.87265 | 0.05604 | 0.88693 | 0.04923 | 0.89969 | 0.04324 | 0.91108 |
| 1.25 | 0.05072 | 0.84131 | 0.04434 | 0.85885 | 0.03876 | 0.87459 | 0.03388 | 0.88869 | 0.02961 | 0.90129 |
| 2 | 0.01825 | 0.80990 | 0.01552 | 0.83075 | 0.01319 | 0.84953 | 0.01122 | 0.86639 | 0.00953 | 0.88149 |
| 3 | 0.01357 | 0.79525 | 0.01149 | 0.81796 | 0.00973 | 0.83840 | 0.00824 | 0.85673 | 0.00698 | 0.87312 |
| 4 | 0.01025 | 0.78453 | 0.00865 | 0.80861 | 0.00730 | 0.83028 | 0.00616 | 0.84969 | 0.00519 | 0.86705 |
| 5 | 0.00552 | 0.77653 | 0.00462 | 0.80165 | 0.00387 | 0.82424 | 0.00323 | 0.84448 | 0.00271 | 0.86256 |
| 10 | 0.00292 | 0.75537 | 0.00242 | 0.78334 | 0.00201 | 0.80846 | 0.00166 | 0.83093 | 0.00138 | 0.85097 |
| 15 | 0.00360 | 0.74443 | 0.00300 | 0.77392 | 0.00249 | 0.80039 | 0.00207 | 0.82405 | 0.00172 | 0.84512 |
| 20 | 0.00495 | 0.73114 | 0.00413 | 0.76241 | 0.00345 | 0.79048 | 0.00288 | 0.81555 | 0.00241 | 0.83786 |
| $_1q_0$ = | | 0.14328 | | 0.12735 | | 0.11307 | | 0.10031 | | 0.08892 |
| $_4q_1$ = | | 0.09361 | | 0.08137 | | 0.07068 | | 0.06137 | | 0.05326 |

## Cameroon

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.56082 | 1.00000 | 0.46293 | 1.00000 | 0.38212 | 1.00000 | 0.31542 | 1.00000 | 0.26036 | 1.00000 |
| 0.0833 | 0.24333 | 0.95433 | 0.21088 | 0.96215 | 0.18276 | 0.96866 | 0.15839 | 0.97406 | 0.13727 | 0.97854 |
| 0.25 | 0.10774 | 0.91640 | 0.09792 | 0.92892 | 0.08899 | 0.93959 | 0.08088 | 0.94868 | 0.07350 | 0.95640 |
| 0.5 | 0.10869 | 0.89204 | 0.09719 | 0.90646 | 0.08691 | 0.91892 | 0.07772 | 0.92969 | 0.06949 | 0.93899 |
| 0.75 | 0.07065 | 0.86813 | 0.06478 | 0.88470 | 0.05940 | 0.89917 | 0.05447 | 0.91180 | 0.04995 | 0.92281 |
| 1 | 0.05071 | 0.85293 | 0.04741 | 0.87048 | 0.04432 | 0.88591 | 0.04144 | 0.89947 | 0.03874 | 0.91136 |
| 1.25 | 0.03151 | 0.84219 | 0.03029 | 0.86023 | 0.02911 | 0.87615 | 0.02798 | 0.89020 | 0.02690 | 0.90258 |
| 2 | 0.00921 | 0.82251 | 0.00966 | 0.84090 | 0.01014 | 0.85723 | 0.01063 | 0.87171 | 0.01115 | 0.88455 |
| 3 | 0.00622 | 0.81497 | 0.00668 | 0.83282 | 0.00717 | 0.84858 | 0.00769 | 0.86249 | 0.00826 | 0.87474 |
| 4 | 0.00429 | 0.80992 | 0.00471 | 0.82727 | 0.00516 | 0.84252 | 0.00566 | 0.85588 | 0.00621 | 0.86755 |
| 5 | 0.00189 | 0.80645 | 0.00218 | 0.82339 | 0.00250 | 0.83818 | 0.00288 | 0.85105 | 0.00331 | 0.86218 |
| 10 | 0.00081 | 0.79886 | 0.00098 | 0.81448 | 0.00119 | 0.82776 | 0.00143 | 0.83888 | 0.00173 | 0.84801 |
| 15 | 0.00107 | 0.79563 | 0.00128 | 0.81050 | 0.00152 | 0.82287 | 0.00180 | 0.83289 | 0.00215 | 0.84070 |
| 20 | 0.00163 | 0.79137 | 0.00189 | 0.80534 | 0.00220 | 0.81665 | 0.00255 | 0.82541 | 0.00296 | 0.83173 |
| $_1q_0$ = | | 0.14707 | | 0.12952 | | 0.11409 | | 0.10053 | | 0.08864 |
| $_4q_1$ = | | 0.05450 | | 0.05410 | | 0.05388 | | 0.05383 | | 0.05397 |

## Chad

| Age (*in yrs*) | 1975 $_nm_x$ | 1975 $l_x$ | 1980 $_nm_x$ | 1980 $l_x$ | 1985 $_nm_x$ | 1985 $l_x$ | 1990 $_nm_x$ | 1990 $l_x$ | 1995 $_nm_x$ | 1995 $l_x$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.65195 | 1.00000 | 0.56933 | 1.00000 | 0.49718 | 1.00000 | 0.43418 | 1.00000 | 0.37916 | 1.00000 |
| 0.0833 | 0.33685 | 0.94711 | 0.29320 | 0.95365 | 0.25520 | 0.95941 | 0.22213 | 0.96446 | 0.19335 | 0.96890 |
| 0.25 | 0.17686 | 0.89539 | 0.15345 | 0.90816 | 0.13314 | 0.91945 | 0.11551 | 0.92940 | 0.10022 | 0.93817 |
| 0.5 | 0.11687 | 0.85665 | 0.11474 | 0.87398 | 0.11264 | 0.88935 | 0.11059 | 0.90295 | 0.10857 | 0.91495 |
| 0.75 | 0.08313 | 0.83199 | 0.08147 | 0.84927 | 0.07985 | 0.86465 | 0.07826 | 0.87832 | 0.07670 | 0.89045 |
| 1 | 0.06396 | 0.81487 | 0.06260 | 0.83214 | 0.06128 | 0.84756 | 0.05998 | 0.86130 | 0.05871 | 0.87354 |
| 1.25 | 0.04390 | 0.80195 | 0.04289 | 0.81922 | 0.04190 | 0.83468 | 0.04094 | 0.84849 | 0.04000 | 0.86081 |
| 2 | 0.02529 | 0.77597 | 0.02173 | 0.79329 | 0.01868 | 0.80885 | 0.01605 | 0.82283 | 0.01379 | 0.83537 |
| 3 | 0.01854 | 0.75659 | 0.01591 | 0.77623 | 0.01365 | 0.79389 | 0.01171 | 0.80973 | 0.01005 | 0.82393 |
| 4 | 0.01382 | 0.74269 | 0.01184 | 0.76398 | 0.01015 | 0.78312 | 0.00869 | 0.80030 | 0.00745 | 0.81569 |
| 5 | 0.00723 | 0.73250 | 0.00617 | 0.75498 | 0.00527 | 0.77522 | 0.00450 | 0.79337 | 0.00385 | 0.80964 |
| 10 | 0.00370 | 0.70649 | 0.00315 | 0.73203 | 0.00268 | 0.75504 | 0.00228 | 0.77571 | 0.00194 | 0.79422 |
| 15 | 0.00462 | 0.69353 | 0.00394 | 0.72059 | 0.00335 | 0.74498 | 0.00286 | 0.76690 | 0.00243 | 0.78654 |
| 20 | 0.00644 | 0.67769 | 0.00549 | 0.70655 | 0.00469 | 0.73260 | 0.00400 | 0.75603 | 0.00342 | 0.77702 |
| $_1q_0$ = | | 0.18513 | | 0.16786 | | 0.15244 | | 0.13870 | | 0.12646 |
| $_4q_1$ = | | 0.10109 | | 0.09272 | | 0.08536 | | 0.07887 | | 0.07315 |

## Central African Republic

| Age (*in yrs*) | 1975 $_nm_x$ | 1975 $l_x$ | 1980 $_nm_x$ | 1980 $l_x$ | 1985 $_nm_x$ | 1985 $l_x$ | 1990 $_nm_x$ | 1990 $l_x$ | 1995 $_nm_x$ | 1995 $l_x$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.50575 | 1.00000 | 0.47745 | 1.00000 | 0.45074 | 1.00000 | 0.42552 | 1.00000 | 0.40171 | 1.00000 |
| 0.0833 | 0.22449 | 0.95872 | 0.21542 | 0.96099 | 0.20671 | 0.96313 | 0.19836 | 0.96516 | 0.19034 | 0.96708 |
| 0.25 | 0.10164 | 0.92351 | 0.09909 | 0.92709 | 0.09661 | 0.93051 | 0.09420 | 0.93377 | 0.09184 | 0.93688 |
| 0.5 | 0.08513 | 0.90034 | 0.08136 | 0.90441 | 0.07776 | 0.90830 | 0.07431 | 0.91204 | 0.07102 | 0.91561 |
| 0.75 | 0.05599 | 0.88138 | 0.05396 | 0.88620 | 0.05201 | 0.89082 | 0.05012 | 0.89525 | 0.04831 | 0.89950 |
| 1 | 0.04056 | 0.86913 | 0.03934 | 0.87432 | 0.03816 | 0.87931 | 0.03702 | 0.88410 | 0.03591 | 0.88870 |
| 1.25 | 0.02553 | 0.86036 | 0.02500 | 0.86576 | 0.02448 | 0.87096 | 0.02396 | 0.87595 | 0.02346 | 0.88075 |
| 2 | 0.00929 | 0.84404 | 0.00951 | 0.84968 | 0.00973 | 0.85512 | 0.00995 | 0.86035 | 0.01018 | 0.86539 |
| 3 | 0.00635 | 0.83623 | 0.00654 | 0.84164 | 0.00674 | 0.84684 | 0.00695 | 0.85183 | 0.00716 | 0.85663 |
| 4 | 0.00442 | 0.83094 | 0.00459 | 0.83616 | 0.00477 | 0.84115 | 0.00495 | 0.84593 | 0.00514 | 0.85051 |
| 5 | 0.00199 | 0.82728 | 0.00210 | 0.83233 | 0.00222 | 0.83715 | 0.00234 | 0.84176 | 0.00247 | 0.84615 |
| 10 | 0.00087 | 0.81908 | 0.00094 | 0.82363 | 0.00101 | 0.82792 | 0.00108 | 0.83197 | 0.00116 | 0.83577 |
| 15 | 0.00115 | 0.81551 | 0.00122 | 0.81977 | 0.00131 | 0.82376 | 0.00139 | 0.82749 | 0.00149 | 0.83095 |
| 20 | 0.00173 | 0.81084 | 0.00183 | 0.81477 | 0.00193 | 0.81840 | 0.00205 | 0.82174 | 0.00217 | 0.82479 |
| $_1q_0$ = | | 0.13087 | | 0.12568 | | 0.12069 | | 0.11590 | | 0.11130 |
| $_4q_1$ = | | 0.04815 | | 0.04803 | | 0.04795 | | 0.04789 | | 0.04787 |

## Uganda

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.36403 | 1.00000 | 0.41218 | 1.00000 | 0.39553 | 1.00000 | 0.32167 | 1.00000 | 0.22172 | 1.00000 |
| 0.0833 | 0.19035 | 0.97012 | 0.20307 | 0.96623 | 0.19023 | 0.96757 | 0.15650 | 0.97355 | 0.11306 | 0.98169 |
| 0.25 | 0.10112 | 0.93982 | 0.10178 | 0.93407 | 0.09314 | 0.93738 | 0.07749 | 0.94848 | 0.05860 | 0.96337 |
| 0.5 | 0.10325 | 0.91636 | 0.10770 | 0.91061 | 0.10486 | 0.91580 | 0.09530 | 0.93028 | 0.08083 | 0.94935 |
| 0.75 | 0.07389 | 0.89301 | 0.07475 | 0.88641 | 0.07188 | 0.89210 | 0.06571 | 0.90838 | 0.05711 | 0.93036 |
| 1 | 0.05712 | 0.87666 | 0.05643 | 0.87000 | 0.05375 | 0.87621 | 0.04937 | 0.89358 | 0.04371 | 0.91717 |
| 1.25 | 0.03948 | 0.86423 | 0.03770 | 0.85781 | 0.03542 | 0.86452 | 0.03274 | 0.88262 | 0.02978 | 0.90721 |
| 2 | 0.01498 | 0.83901 | 0.01265 | 0.83390 | 0.01079 | 0.84185 | 0.00928 | 0.86121 | 0.00806 | 0.88717 |
| 3 | 0.01105 | 0.82654 | 0.00907 | 0.82341 | 0.00765 | 0.83282 | 0.00662 | 0.85325 | 0.00588 | 0.88004 |
| 4 | 0.00828 | 0.81746 | 0.00662 | 0.81598 | 0.00552 | 0.82647 | 0.00480 | 0.84762 | 0.00435 | 0.87489 |
| 5 | 0.00438 | 0.81072 | 0.00330 | 0.81059 | 0.00269 | 0.82192 | 0.00237 | 0.84356 | 0.00225 | 0.87109 |
| 10 | 0.00227 | 0.79316 | 0.00161 | 0.79731 | 0.00128 | 0.81094 | 0.00114 | 0.83364 | 0.00114 | 0.86135 |
| 15 | 0.00282 | 0.78420 | 0.00204 | 0.79090 | 0.00164 | 0.80575 | 0.00145 | 0.82890 | 0.00142 | 0.85647 |
| 20 | 0.00391 | 0.77322 | 0.00292 | 0.78286 | 0.00237 | 0.79918 | 0.00209 | 0.82290 | 0.00200 | 0.85040 |
| $_1q_0$ = | | 0.12334 | | 0.13000 | | 0.12379 | | 0.10642 | | 0.08283 |
| $_4q_1$ = | | 0.07522 | | 0.06829 | | 0.06196 | | 0.05597 | | 0.05025 |

## Kenya

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.29302 | 1.00000 | 0.26364 | 1.00000 | 0.25316 | 1.00000 | 0.25943 | 1.00000 | 0.28374 | 1.00000 |
| 0.0833 | 0.13911 | 0.97588 | 0.11852 | 0.97827 | 0.11094 | 0.97912 | 0.11409 | 0.97861 | 0.12890 | 0.97663 |
| 0.25 | 0.06725 | 0.95351 | 0.05433 | 0.95913 | 0.04960 | 0.96119 | 0.05118 | 0.96018 | 0.05969 | 0.95587 |
| 0.5 | 0.04903 | 0.93761 | 0.04601 | 0.94619 | 0.04580 | 0.94934 | 0.04835 | 0.94797 | 0.05415 | 0.94172 |
| 0.75 | 0.03338 | 0.92619 | 0.03046 | 0.93537 | 0.02992 | 0.93853 | 0.03165 | 0.93658 | 0.03604 | 0.92905 |
| 1 | 0.02484 | 0.91849 | 0.02217 | 0.92828 | 0.02156 | 0.93154 | 0.02284 | 0.92920 | 0.02635 | 0.92072 |
| 1.25 | 0.01625 | 0.91281 | 0.01406 | 0.92315 | 0.01348 | 0.92653 | 0.01430 | 0.92391 | 0.01681 | 0.91468 |
| 2 | 0.00750 | 0.90175 | 0.00516 | 0.91346 | 0.00437 | 0.91721 | 0.00455 | 0.91405 | 0.00584 | 0.90322 |
| 3 | 0.00528 | 0.89502 | 0.00354 | 0.90876 | 0.00296 | 0.91321 | 0.00310 | 0.90990 | 0.00403 | 0.89796 |
| 4 | 0.00379 | 0.89030 | 0.00248 | 0.90555 | 0.00205 | 0.91051 | 0.00215 | 0.90709 | 0.00284 | 0.89434 |
| 5 | 0.00183 | 0.88694 | 0.00113 | 0.90331 | 0.00091 | 0.90864 | 0.00096 | 0.90514 | 0.00131 | 0.89181 |
| 10 | 0.00086 | 0.87888 | 0.00050 | 0.89821 | 0.00040 | 0.90450 | 0.00042 | 0.90081 | 0.00059 | 0.88599 |
| 15 | 0.00110 | 0.87512 | 0.00066 | 0.89595 | 0.00052 | 0.90271 | 0.00055 | 0.89894 | 0.00077 | 0.88339 |
| 20 | 0.00160 | 0.87031 | 0.00098 | 0.89300 | 0.00079 | 0.90036 | 0.00083 | 0.89647 | 0.00114 | 0.88001 |
| $_1q_0$ = | | 0.08151 | | 0.07172 | | 0.06846 | | 0.07080 | | 0.07928 |
| $_4q_1$ = | | 0.03436 | | 0.02690 | | 0.02458 | | 0.02589 | | 0.03140 |

## Tanzania

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.41278 | 1.00000 | 0.40591 | 1.00000 | 0.39917 | 1.00000 | 0.39253 | 1.00000 | 0.38600 | 1.00000 |
| 0.0833 | 0.20295 | 0.96618 | 0.19521 | 0.96674 | 0.18776 | 0.96728 | 0.18060 | 0.96782 | 0.17371 | 0.96834 |
| 0.25 | 0.10152 | 0.93405 | 0.09556 | 0.93579 | 0.08996 | 0.93748 | 0.08468 | 0.93912 | 0.07971 | 0.94071 |
| 0.5 | 0.09955 | 0.91064 | 0.09232 | 0.91369 | 0.08561 | 0.91663 | 0.07939 | 0.91944 | 0.07362 | 0.92215 |
| 0.75 | 0.06902 | 0.88825 | 0.06328 | 0.89285 | 0.05801 | 0.89722 | 0.05319 | 0.90137 | 0.04876 | 0.90533 |
| 1 | 0.05207 | 0.87306 | 0.04732 | 0.87883 | 0.04300 | 0.88430 | 0.03908 | 0.88947 | 0.03552 | 0.89436 |
| 1.25 | 0.03474 | 0.86176 | 0.03118 | 0.86850 | 0.02798 | 0.87484 | 0.02511 | 0.88082 | 0.02253 | 0.88645 |
| 2 | 0.01254 | 0.83960 | 0.01106 | 0.84842 | 0.00976 | 0.85667 | 0.00861 | 0.86439 | 0.00759 | 0.87160 |
| 3 | 0.00899 | 0.82913 | 0.00784 | 0.83909 | 0.00685 | 0.84835 | 0.00598 | 0.85698 | 0.00522 | 0.86501 |
| 4 | 0.00655 | 0.82171 | 0.00566 | 0.83253 | 0.00489 | 0.84257 | 0.00423 | 0.85187 | 0.00366 | 0.86051 |
| 5 | 0.00326 | 0.81635 | 0.00276 | 0.82783 | 0.00233 | 0.83845 | 0.00197 | 0.84828 | 0.00167 | 0.85737 |
| 10 | 0.00159 | 0.80313 | 0.00131 | 0.81648 | 0.00109 | 0.82872 | 0.00090 | 0.83994 | 0.00074 | 0.85024 |
| 15 | 0.00202 | 0.79677 | 0.00168 | 0.81113 | 0.00140 | 0.82423 | 0.00117 | 0.83618 | 0.00097 | 0.84708 |
| 20 | 0.00288 | 0.78878 | 0.00243 | 0.80435 | 0.00204 | 0.81848 | 0.00172 | 0.83132 | 0.00145 | 0.84298 |
| $_1q_0$ = | | 0.12694 | | 0.12117 | | 0.11570 | | 0.11053 | | 0.10564 |
| $_4q_1$ = | | 0.06495 | | 0.05803 | | 0.05184 | | 0.04631 | | 0.04136 |

## Rwanda

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.40421 | 1.00000 | 0.44790 | 1.00000 | 0.41594 | 1.00000 | 0.32372 | 1.00000 | 0.21115 | 1.00000 |
| 0.0833 | 0.26573 | 0.96687 | 0.24808 | 0.96336 | 0.21304 | 0.96593 | 0.16829 | 0.97338 | 0.12228 | 0.98256 |
| 0.25 | 0.17649 | 0.92498 | 0.13940 | 0.92433 | 0.11091 | 0.93223 | 0.08889 | 0.94646 | 0.07177 | 0.96273 |
| 0.5 | 0.13329 | 0.88505 | 0.09851 | 0.89267 | 0.07859 | 0.90674 | 0.06766 | 0.92566 | 0.06288 | 0.94562 |
| 0.75 | 0.10736 | 0.85604 | 0.07263 | 0.87096 | 0.05565 | 0.88909 | 0.04828 | 0.91013 | 0.04744 | 0.93087 |
| 1 | 0.09089 | 0.83337 | 0.05745 | 0.85528 | 0.04267 | 0.87681 | 0.03724 | 0.89921 | 0.03819 | 0.91989 |
| 1.25 | 0.07157 | 0.81464 | 0.04103 | 0.84309 | 0.02914 | 0.86751 | 0.02565 | 0.89088 | 0.02798 | 0.91115 |
| 2 | 0.05131 | 0.77206 | 0.02447 | 0.81754 | 0.01546 | 0.84875 | 0.01294 | 0.87390 | 0.01436 | 0.89223 |
| 3 | 0.04213 | 0.73344 | 0.01853 | 0.79778 | 0.01129 | 0.83573 | 0.00952 | 0.86266 | 0.01111 | 0.87951 |
| 4 | 0.03496 | 0.70317 | 0.01425 | 0.78313 | 0.00838 | 0.82635 | 0.00711 | 0.85449 | 0.00871 | 0.86979 |
| 5 | 0.02316 | 0.67902 | 0.00798 | 0.77205 | 0.00435 | 0.81945 | 0.00374 | 0.84843 | 0.00510 | 0.86224 |
| 10 | 0.01514 | 0.60468 | 0.00439 | 0.74185 | 0.00221 | 0.80183 | 0.00193 | 0.83270 | 0.00293 | 0.84054 |
| 15 | 0.01742 | 0.56057 | 0.00534 | 0.72576 | 0.00276 | 0.79304 | 0.00240 | 0.82471 | 0.00352 | 0.82831 |
| 20 | 0.02152 | 0.51377 | 0.00719 | 0.70662 | 0.00386 | 0.78217 | 0.00334 | 0.81486 | 0.00463 | 0.81387 |
| $_1q_0$ = | | 0.16663 | | 0.14472 | | 0.12319 | | 0.10079 | | 0.08011 |
| $_4q_1$ = | | 0.18522 | | 0.09732 | | 0.06542 | | 0.05647 | | 0.06267 |

## Burundi

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.35665 | 1.00000 | 0.36880 | 1.00000 | 0.26661 | 1.00000 | 0.13474 | 1.00000 | 0.04761 | 1.00000 |
| 0.0833 | 0.20596 | 0.97071 | 0.20709 | 0.96973 | 0.14558 | 0.97803 | 0.07154 | 0.98883 | 0.02458 | 0.99604 |
| 0.25 | 0.12053 | 0.93796 | 0.11793 | 0.93683 | 0.08067 | 0.95458 | 0.03857 | 0.97711 | 0.01290 | 0.99197 |
| 0.5 | 0.13443 | 0.91011 | 0.11099 | 0.90961 | 0.06406 | 0.93552 | 0.02585 | 0.96774 | 0.00729 | 0.98878 |
| 0.75 | 0.10126 | 0.88003 | 0.08241 | 0.88472 | 0.04689 | 0.92066 | 0.01865 | 0.96150 | 0.00519 | 0.98697 |
| 1 | 0.08143 | 0.85803 | 0.06554 | 0.86667 | 0.03687 | 0.90993 | 0.01450 | 0.95703 | 0.00399 | 0.98570 |
| 1.25 | 0.05955 | 0.84074 | 0.04717 | 0.85259 | 0.02612 | 0.90158 | 0.01011 | 0.95357 | 0.00274 | 0.98471 |
| 2 | 0.02392 | 0.80401 | 0.02155 | 0.82295 | 0.01357 | 0.88409 | 0.00598 | 0.94636 | 0.00184 | 0.98269 |
| 3 | 0.01848 | 0.78501 | 0.01643 | 0.80541 | 0.01021 | 0.87217 | 0.00444 | 0.94072 | 0.00135 | 0.98089 |
| 4 | 0.01447 | 0.77063 | 0.01271 | 0.79228 | 0.00780 | 0.86331 | 0.00335 | 0.93655 | 0.00100 | 0.97957 |
| 5 | 0.00844 | 0.75956 | 0.00721 | 0.78227 | 0.00431 | 0.85660 | 0.00180 | 0.93342 | 0.00053 | 0.97858 |
| 10 | 0.00484 | 0.72816 | 0.00402 | 0.75456 | 0.00233 | 0.83834 | 0.00095 | 0.92506 | 0.00027 | 0.97602 |
| 15 | 0.00582 | 0.71074 | 0.00488 | 0.73954 | 0.00286 | 0.82861 | 0.00117 | 0.92069 | 0.00034 | 0.97470 |
| 20 | 0.00767 | 0.69037 | 0.00652 | 0.72173 | 0.00387 | 0.81685 | 0.00161 | 0.91532 | 0.00047 | 0.97307 |
| $_1q_0$ = | | 0.14197 | | 0.13333 | | 0.09007 | | 0.04297 | | 0.01430 |
| $_4q_1$ = | | 0.11476 | | 0.09738 | | 0.05861 | | 0.02467 | | 0.00722 |

## Ethiopia

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.16956 | 1.00000 | 0.34280 | 1.00000 | 0.51847 | 1.00000 | 0.58666 | 1.00000 | 0.49663 | 1.00000 |
| 0.0833 | 0.08495 | 0.98597 | 0.17128 | 0.97184 | 0.25835 | 0.95771 | 0.29154 | 0.95228 | 0.24613 | 0.95945 |
| 0.25 | 0.04328 | 0.97211 | 0.08704 | 0.94448 | 0.13094 | 0.91734 | 0.14737 | 0.90710 | 0.12408 | 0.92089 |
| 0.5 | 0.02317 | 0.96164 | 0.04990 | 0.92415 | 0.08040 | 0.88779 | 0.09693 | 0.87429 | 0.08742 | 0.89276 |
| 0.75 | 0.01622 | 0.95609 | 0.03488 | 0.91270 | 0.05613 | 0.87013 | 0.06757 | 0.85336 | 0.06086 | 0.87345 |
| 1 | 0.01233 | 0.95222 | 0.02648 | 0.90477 | 0.04257 | 0.85800 | 0.05119 | 0.83906 | 0.04606 | 0.86027 |
| 1.25 | 0.00831 | 0.94929 | 0.01783 | 0.89880 | 0.02862 | 0.84892 | 0.03437 | 0.82839 | 0.03087 | 0.85042 |
| 2 | 0.00565 | 0.94339 | 0.01128 | 0.88686 | 0.01683 | 0.83089 | 0.01879 | 0.80731 | 0.01570 | 0.83095 |
| 3 | 0.00409 | 0.93807 | 0.00814 | 0.87691 | 0.01213 | 0.81702 | 0.01353 | 0.79228 | 0.01129 | 0.81801 |
| 4 | 0.00300 | 0.93425 | 0.00598 | 0.86981 | 0.00890 | 0.80717 | 0.00991 | 0.78164 | 0.00826 | 0.80883 |
| 5 | 0.00152 | 0.93145 | 0.00303 | 0.86462 | 0.00449 | 0.80002 | 0.00499 | 0.77393 | 0.00415 | 0.80218 |
| 10 | 0.00076 | 0.92437 | 0.00150 | 0.85164 | 0.00222 | 0.78225 | 0.00246 | 0.75486 | 0.00204 | 0.78572 |
| 15 | 0.00095 | 0.92088 | 0.00189 | 0.84529 | 0.00280 | 0.77362 | 0.00310 | 0.74564 | 0.00258 | 0.77776 |
| 20 | 0.00135 | 0.91650 | 0.00268 | 0.83734 | 0.00397 | 0.76287 | 0.00441 | 0.73416 | 0.00367 | 0.76781 |
| $_1q_0$ = | | 0.04778 | | 0.09523 | | 0.14200 | | 0.16094 | | 0.13973 |
| $_4q_1$ = | | 0.02182 | | 0.04438 | | 0.06758 | | 0.07763 | | 0.06752 |

**Malawi**

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.54025 | 1.00000 | 0.51166 | 1.00000 | 0.48459 | 1.00000 | 0.45895 | 1.00000 | 0.43467 | 1.00000 |
| 0.0833 | 0.29992 | 0.95597 | 0.27619 | 0.95825 | 0.25434 | 0.96042 | 0.23422 | 0.96247 | 0.21569 | 0.96442 |
| 0.25 | 0.16890 | 0.90935 | 0.15134 | 0.91513 | 0.13560 | 0.92055 | 0.12151 | 0.92562 | 0.10887 | 0.93036 |
| 0.5 | 0.14751 | 0.87175 | 0.14338 | 0.88115 | 0.13937 | 0.88986 | 0.13547 | 0.89792 | 0.13168 | 0.90538 |
| 0.75 | 0.10888 | 0.84018 | 0.10431 | 0.85012 | 0.09994 | 0.85939 | 0.09575 | 0.86802 | 0.09173 | 0.87606 |
| 1 | 0.08619 | 0.81762 | 0.08166 | 0.82824 | 0.07737 | 0.83818 | 0.07331 | 0.84749 | 0.06945 | 0.85620 |
| 1.25 | 0.06164 | 0.80019 | 0.05747 | 0.81150 | 0.05359 | 0.82212 | 0.04997 | 0.83210 | 0.04659 | 0.84146 |
| 2 | 0.02984 | 0.76403 | 0.02462 | 0.77726 | 0.02031 | 0.78973 | 0.01676 | 0.80149 | 0.01382 | 0.81256 |
| 3 | 0.02263 | 0.74156 | 0.01843 | 0.75836 | 0.01500 | 0.77385 | 0.01222 | 0.78817 | 0.00995 | 0.80141 |
| 4 | 0.01742 | 0.72497 | 0.01401 | 0.74451 | 0.01126 | 0.76233 | 0.00906 | 0.77860 | 0.00728 | 0.79348 |
| 5 | 0.00978 | 0.71245 | 0.00765 | 0.73415 | 0.00598 | 0.75379 | 0.00468 | 0.77158 | 0.00366 | 0.78772 |
| 10 | 0.00539 | 0.67845 | 0.00409 | 0.70661 | 0.00311 | 0.73158 | 0.00237 | 0.75374 | 0.00180 | 0.77343 |
| 15 | 0.00656 | 0.66043 | 0.00503 | 0.69229 | 0.00386 | 0.72028 | 0.00296 | 0.74487 | 0.00228 | 0.76650 |
| 20 | 0.00882 | 0.63912 | 0.00686 | 0.67508 | 0.00534 | 0.70650 | 0.00416 | 0.73391 | 0.00324 | 0.75784 |
| $_1q_0$ = | | 0.18238 | | 0.17176 | | 0.16182 | | 0.15251 | | 0.14380 |
| $_4q_1$ = | | 0.12863 | | 0.11360 | | 0.10068 | | 0.08957 | | 0.07998 |

**Zambia**

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.23271 | 1.00000 | 0.28776 | 1.00000 | 0.33420 | 1.00000 | 0.36454 | 1.00000 | 0.37346 | 1.00000 |
| 0.0833 | 0.12313 | 0.98079 | 0.14824 | 0.97630 | 0.16762 | 0.97253 | 0.17800 | 0.97008 | 0.17754 | 0.96936 |
| 0.25 | 0.06617 | 0.96087 | 0.07761 | 0.95248 | 0.08549 | 0.94574 | 0.08845 | 0.94172 | 0.08594 | 0.94109 |
| 0.5 | 0.06678 | 0.94511 | 0.08722 | 0.93418 | 0.10700 | 0.92574 | 0.12328 | 0.92112 | 0.13341 | 0.92108 |
| 0.75 | 0.04808 | 0.92946 | 0.06194 | 0.91402 | 0.07495 | 0.90130 | 0.08517 | 0.89316 | 0.09090 | 0.89087 |
| 1 | 0.03735 | 0.91835 | 0.04760 | 0.89998 | 0.05699 | 0.88457 | 0.06408 | 0.87435 | 0.06767 | 0.87085 |
| 1.25 | 0.02599 | 0.90982 | 0.03262 | 0.88933 | 0.03846 | 0.87206 | 0.04259 | 0.86045 | 0.04430 | 0.85624 |
| 2 | 0.01015 | 0.89226 | 0.01100 | 0.86784 | 0.01120 | 0.84726 | 0.01071 | 0.83340 | 0.00962 | 0.82826 |
| 3 | 0.00753 | 0.88325 | 0.00806 | 0.85834 | 0.00810 | 0.83782 | 0.00765 | 0.82452 | 0.00678 | 0.82033 |
| 4 | 0.00567 | 0.87662 | 0.00600 | 0.85145 | 0.00596 | 0.83107 | 0.00556 | 0.81824 | 0.00487 | 0.81479 |
| 5 | 0.00304 | 0.87167 | 0.00313 | 0.84636 | 0.00303 | 0.82613 | 0.00275 | 0.81370 | 0.00235 | 0.81083 |
| 10 | 0.00159 | 0.85854 | 0.00160 | 0.83323 | 0.00150 | 0.81372 | 0.00133 | 0.80259 | 0.00111 | 0.80137 |
| 15 | 0.00197 | 0.85173 | 0.00199 | 0.82660 | 0.00189 | 0.80763 | 0.00169 | 0.79727 | 0.00142 | 0.79695 |
| 20 | 0.00271 | 0.84338 | 0.00278 | 0.81840 | 0.00268 | 0.80001 | 0.00243 | 0.79056 | 0.00206 | 0.79132 |
| $_1q_0$ = | | 0.08165 | | 0.10002 | | 0.11543 | | 0.12565 | | 0.12915 |
| $_4q_1$ = | | 0.05083 | | 0.05957 | | 0.06607 | | 0.06936 | | 0.06892 |

## Mozambique

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.07787 | 1.00000 | 0.25176 | 1.00000 | 0.51013 | 1.00000 | 0.64784 | 1.00000 | 0.51561 | 1.00000 |
| 0.0833 | 0.03650 | 0.99353 | 0.11826 | 0.97924 | 0.24017 | 0.95837 | 0.30569 | 0.94743 | 0.24384 | 0.95794 |
| 0.25 | 0.01742 | 0.98751 | 0.05658 | 0.96013 | 0.11516 | 0.92076 | 0.14690 | 0.90036 | 0.11743 | 0.91978 |
| 0.5 | 0.02674 | 0.98321 | 0.07246 | 0.94664 | 0.12303 | 0.89463 | 0.13092 | 0.86789 | 0.08731 | 0.89317 |
| 0.75 | 0.01809 | 0.97666 | 0.04907 | 0.92964 | 0.08341 | 0.86753 | 0.08886 | 0.83995 | 0.05933 | 0.87388 |
| 1 | 0.01339 | 0.97226 | 0.03635 | 0.91831 | 0.06185 | 0.84963 | 0.06595 | 0.82149 | 0.04407 | 0.86102 |
| 1.25 | 0.00870 | 0.96901 | 0.02363 | 0.91000 | 0.04026 | 0.83659 | 0.04299 | 0.80806 | 0.02876 | 0.85158 |
| 2 | 0.00187 | 0.96271 | 0.00611 | 0.89401 | 0.01252 | 0.81170 | 0.01608 | 0.78242 | 0.01294 | 0.83341 |
| 3 | 0.00131 | 0.96091 | 0.00429 | 0.88856 | 0.00879 | 0.80160 | 0.01130 | 0.76994 | 0.00910 | 0.82269 |
| 4 | 0.00093 | 0.95965 | 0.00306 | 0.88476 | 0.00629 | 0.79459 | 0.00809 | 0.76129 | 0.00652 | 0.81524 |
| 5 | 0.00044 | 0.95875 | 0.00146 | 0.88206 | 0.00300 | 0.78961 | 0.00387 | 0.75515 | 0.00313 | 0.80994 |
| 10 | 0.00021 | 0.95663 | 0.00068 | 0.87565 | 0.00140 | 0.77784 | 0.00181 | 0.74068 | 0.00146 | 0.79737 |
| 15 | 0.00027 | 0.95564 | 0.00087 | 0.87268 | 0.00180 | 0.77242 | 0.00232 | 0.73402 | 0.00188 | 0.79156 |
| 20 | 0.00039 | 0.95437 | 0.00128 | 0.86888 | 0.00263 | 0.76550 | 0.00339 | 0.72553 | 0.00274 | 0.78414 |
| $_1q_0$ = | | 0.02774 | | 0.08169 | | 0.15037 | | 0.17851 | | 0.13898 |
| $_4q_1$ = | | 0.01389 | | 0.03948 | | 0.07064 | | 0.08075 | | 0.05932 |

## Zimbabwe

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.33193 | 1.00000 | 0.25121 | 1.00000 | 0.21898 | 1.00000 | 0.21985 | 1.00000 | 0.25421 | 1.00000 |
| 0.0833 | 0.14028 | 0.97272 | 0.10585 | 0.97928 | 0.09198 | 0.98192 | 0.09206 | 0.98185 | 0.10613 | 0.97904 |
| 0.25 | 0.06054 | 0.95024 | 0.04554 | 0.96216 | 0.03946 | 0.96698 | 0.03938 | 0.96689 | 0.04526 | 0.96187 |
| 0.5 | 0.06863 | 0.93596 | 0.04981 | 0.95127 | 0.04164 | 0.95749 | 0.04009 | 0.95742 | 0.04445 | 0.95105 |
| 0.75 | 0.04401 | 0.92004 | 0.03189 | 0.93949 | 0.02662 | 0.94757 | 0.02559 | 0.94788 | 0.02833 | 0.94054 |
| 1 | 0.03127 | 0.90997 | 0.02263 | 0.93203 | 0.01886 | 0.94129 | 0.01811 | 0.94183 | 0.02003 | 0.93390 |
| 1.25 | 0.01914 | 0.90289 | 0.01383 | 0.92677 | 0.01151 | 0.93686 | 0.01103 | 0.93758 | 0.01217 | 0.92924 |
| 2 | 0.00479 | 0.89002 | 0.00357 | 0.91721 | 0.00307 | 0.92881 | 0.00303 | 0.92985 | 0.00345 | 0.92079 |
| 3 | 0.00320 | 0.88577 | 0.00238 | 0.91394 | 0.00204 | 0.92596 | 0.00201 | 0.92704 | 0.00229 | 0.91762 |
| 4 | 0.00218 | 0.88294 | 0.00162 | 0.91177 | 0.00139 | 0.92408 | 0.00137 | 0.92517 | 0.00155 | 0.91551 |
| 5 | 0.00094 | 0.88102 | 0.00069 | 0.91029 | 0.00059 | 0.92279 | 0.00058 | 0.92391 | 0.00066 | 0.91409 |
| 10 | 0.00039 | 0.87691 | 0.00029 | 0.90714 | 0.00025 | 0.92007 | 0.00024 | 0.92122 | 0.00027 | 0.91109 |
| 15 | 0.00052 | 0.87519 | 0.00039 | 0.90583 | 0.00033 | 0.91894 | 0.00032 | 0.92011 | 0.00036 | 0.90985 |
| 20 | 0.00080 | 0.87291 | 0.00060 | 0.90409 | 0.00051 | 0.91743 | 0.00050 | 0.91863 | 0.00057 | 0.90819 |
| $_1q_0$ = | | 0.09003 | | 0.06797 | | 0.05871 | | 0.05817 | | 0.06610 |
| $_4q_1$ = | | 0.03182 | | 0.02332 | | 0.01964 | | 0.01903 | | 0.02121 |

### Namibia

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 0.40822 | 1.00000 | 0.36105 | 1.00000 | 0.31934 | 1.00000 | 0.28244 | 1.00000 | 0.24981 | 1.00000 |
| 0.0833 | 0.16731 | 0.96655 | 0.14978 | 0.97036 | 0.13409 | 0.97374 | 0.12004 | 0.97674 | 0.10746 | 0.97940 |
| 0.25 | 0.07008 | 0.93997 | 0.06348 | 0.94643 | 0.05750 | 0.95222 | 0.05209 | 0.95739 | 0.04718 | 0.96201 |
| 0.5 | 0.08183 | 0.92364 | 0.05976 | 0.93153 | 0.04365 | 0.93863 | 0.03188 | 0.94500 | 0.02328 | 0.95073 |
| 0.75 | 0.05165 | 0.90494 | 0.03796 | 0.91772 | 0.02790 | 0.92844 | 0.02050 | 0.93750 | 0.01507 | 0.94521 |
| 1 | 0.03625 | 0.89333 | 0.02677 | 0.90905 | 0.01977 | 0.92199 | 0.01460 | 0.93271 | 0.01078 | 0.94166 |
| 1.25 | 0.02180 | 0.88527 | 0.01621 | 0.90299 | 0.01206 | 0.91744 | 0.00896 | 0.92931 | 0.00666 | 0.93913 |
| 2 | 0.00507 | 0.87091 | 0.00476 | 0.89207 | 0.00446 | 0.90919 | 0.00419 | 0.92309 | 0.00393 | 0.93444 |
| 3 | 0.00333 | 0.86651 | 0.00315 | 0.88784 | 0.00297 | 0.90514 | 0.00280 | 0.91923 | 0.00265 | 0.93078 |
| 4 | 0.00224 | 0.86363 | 0.00213 | 0.88505 | 0.00202 | 0.90245 | 0.00192 | 0.91665 | 0.00182 | 0.92832 |
| 5 | 0.00093 | 0.86170 | 0.00090 | 0.88317 | 0.00086 | 0.90063 | 0.00083 | 0.91490 | 0.00079 | 0.92663 |
| 10 | 0.00038 | 0.85768 | 0.00037 | 0.87922 | 0.00036 | 0.89676 | 0.00035 | 0.91112 | 0.00034 | 0.92296 |
| 15 | 0.00051 | 0.85606 | 0.00049 | 0.87761 | 0.00048 | 0.89516 | 0.00046 | 0.90954 | 0.00045 | 0.92140 |
| 20 | 0.00080 | 0.85388 | 0.00077 | 0.87545 | 0.00074 | 0.89303 | 0.00071 | 0.90744 | 0.00068 | 0.91934 |
| $_1q_0$ = | | 0.10667 | | 0.09095 | | 0.07801 | | 0.06729 | | 0.05834 |
| $_4q_1$ = | | 0.03541 | | 0.02847 | | 0.02316 | | 0.01909 | | 0.01596 |

### South Africa

| Age (*in yrs*) | 1975 | | 1980 | | 1985 | | 1990 | | 1995 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ | $_nm_x$ | $l_x$ |
| 0 | 1.89329 | 1.00000 | 0.53563 | 1.00000 | 0.24124 | 1.00000 | 0.17298 | 1.00000 | 0.19747 | 1.00000 |
| 0.0833 | 0.73060 | 0.85376 | 0.20381 | 0.95634 | 0.09052 | 0.98010 | 0.06400 | 0.98569 | 0.07204 | 0.98368 |
| 0.25 | 0.28853 | 0.75577 | 0.07940 | 0.92440 | 0.03478 | 0.96542 | 0.02426 | 0.97523 | 0.02694 | 0.97194 |
| 0.5 | 0.28705 | 0.70315 | 0.07917 | 0.90623 | 0.03476 | 0.95706 | 0.02430 | 0.96933 | 0.02704 | 0.96542 |
| 0.75 | 0.17563 | 0.65444 | 0.04809 | 0.88847 | 0.02096 | 0.94878 | 0.01455 | 0.96346 | 0.01607 | 0.95891 |
| 1 | 0.12034 | 0.62632 | 0.03277 | 0.87785 | 0.01420 | 0.94382 | 0.00980 | 0.95996 | 0.01077 | 0.95507 |
| 1.25 | 0.06995 | 0.60776 | 0.01889 | 0.87069 | 0.00813 | 0.94048 | 0.00556 | 0.95762 | 0.00606 | 0.95250 |
| 2 | 0.01747 | 0.57669 | 0.00461 | 0.85844 | 0.00194 | 0.93476 | 0.00130 | 0.95363 | 0.00138 | 0.94818 |
| 3 | 0.01117 | 0.56670 | 0.00293 | 0.85449 | 0.00122 | 0.93295 | 0.00081 | 0.95239 | 0.00086 | 0.94687 |
| 4 | 0.00731 | 0.56041 | 0.00191 | 0.85199 | 0.00079 | 0.93181 | 0.00052 | 0.95162 | 0.00055 | 0.94605 |
| 5 | 0.00287 | 0.55633 | 0.00074 | 0.85037 | 0.00030 | 0.93108 | 0.00020 | 0.95112 | 0.00020 | 0.94553 |
| 10 | 0.00109 | 0.54840 | 0.00028 | 0.84723 | 0.00011 | 0.92967 | 0.00007 | 0.95018 | 0.00007 | 0.94457 |
| 15 | 0.00150 | 0.54541 | 0.00038 | 0.84606 | 0.00016 | 0.92915 | 0.00010 | 0.94984 | 0.00010 | 0.94422 |
| 20 | 0.00243 | 0.54132 | 0.00062 | 0.84444 | 0.00025 | 0.92843 | 0.00017 | 0.94937 | 0.00017 | 0.94373 |
| $_1q_0$ = | | 0.37368 | | 0.12215 | | 0.05618 | | 0.04004 | | 0.04493 |
| $_4q_1$ = | | 0.11175 | | 0.03131 | | 0.01351 | | 0.00921 | | 0.00998 |