HELIGMAN POLLARD MODELLING OF REGIONAL DIFFERENTIAL IN UNDER-FIVE MORTALITY IN NIGERIA

BY

AFAM, BRIDGET OGOCHUKWU
B.Sc. PHYSIOLOGY (ASABA)
MATRIC NUMBER: 196481

A DISSERTATION SUBMITTED TO
THE DEPARTMENT OF EPIDEMIOLOGY AND MEDICAL STATISTICS,
FACULTY OF PUBLIC HEALTH, COLLEGE OF MEDICINE,
UNIVERSITY OF IBADAN.

IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE AWARD OF
MASTERS IN PUBLIC HEALTH DEGREE IN MEDICAL DEMOGRAPHY
OF THE UNIVERSITY OF IBADAN

FEBRUARY, 2018.

ABSTRACT

Childhood mortality remains an issue of public health concern in Nigeria. Accurate estimates of childhood mortality are useful indices for combating the menace of child mortality in various regions of the country. They are useful in planning, implementation and evaluation of health programmes. Numerous studies have been conducted on provision of childhood mortality estimates in Nigeria using both direct and indirect methods, the use of the Heligman Pollard model have not been extensively documented in Nigeria. Thus, this study provided estimates of childhood mortality for Nigeria and its geopolitical zones using the Heligman Pollard model.

Demographic parameters were estimated from Nigeria Demographic and Health Survey. Information on children ever born and children dead were used for child mortality estimation, while adult mortality was estimated using survival of siblings method. The childhood and adult mortality estimates were linked using the logit life table system. Mortality estimates of the Heligman pollard model were generated by applying the fitted values of probability of death obtained from the life tables into the Heligman pollard model formula.

There were regional variations in the levels of infant and under-five mortality in Nigeria. The infant and under-five mortality were highest in the North West and least in South West. There was a downward trend in the survivorship probabilities as age increased. The age patterns of childhood and adult mortality were similar across all regions. The estimated life expectancies varied among the regions with North Central having a life expectancy of 59, North East – 62, North West - 60, South East - 59, South South - 63 and South West – 65. Life expectancy from birth in Nigeria was 58 years. The probability of dying at infancy was 0.075, 0.089 and 0.106 in the northern regions of the country and 0.072, 0.072 and 0.058 in the southern regions respectively.

Childhood mortality estimates in Nigeria obtained from the Heligman Pollard model were high, although the pattern of childhood mortality was found to be similar across the regions in Nigeria but variation exists in the childhood mortality estimates. While government should not relent their efforts in alleviating childhood mortality in Nigeria, more attention should be focused on children who live in the North East and North West part of Nigeria.

Keyword: Childhood mortality, Survivorship probability, Heligman-Pollard.

Word count: 369

CERTIFICATION

We certify that this project was carried out under our supervision by Afam, Bridget Ogochukwu of the Department of Epidemiology and Medical Statistics, Faculty of Public Health, College of Medicine, University of Ibadan.

SUPERVISOR
DR. ADEBOWALE, S. A
B.Sc. (ADO), P. G.D (Computer Sc.), M.Sc. (LAGOS), M.Sc. Ph.D. (Ife),
Res. Fellow (SOUTH AFRICA)
DEPARTMENT OF EPIDEMIOLOGY AND MEDICAL STATISTICS,
FACULTY OF PUBLIC HEALTH,
COLLEGE OF MEDICINE,
UNIVERSITY OF IBADAN

CO-SUPERVISOR
DR. GBADEBO, B. M
B.Sc. M.Sc. Ph.D. (Ife)
DEPARTMENT OF EPIDEMIOLOGY AND MEDICAL STATISTICS,
FACULTY OF PUBLIC HEALTH,
COLLEGE OF MEDICINE,
UNIVERSITY OF IBADAN

DEDICATION

This project is dedicated to God Almighty for His protection over my life.

ACKNOWLEDGEMENTS

First and foremost, my unalloyed appreciation goes to the Almighty God for his unfathomable love which, against all odds, has made it possible for me to reach this level of academics in my life time. My sincere appreciation goes to my supervisor, Dr. Adebowale for his immeasurable professional guidance and unrelenting effort in correcting and seeing that every aspect of this dissertation follows the right course. I also appreciate Dr. Gbadebo for his professional guidance and support in making this dissertation a success. I sincerely appreciate the Head of the Department of Epidemiology and Medical Statistics, Dr. Bidemi Yusuf and all the lecturers in the department.

My profound gratitude goes to my parents; Mr. & Mrs. Afam for their unflinching support, encouragement and interest in my career and to my siblings for their love, encouragement and prayers. Finally, I sincerely appreciate the technical and moral support given to me by Mr. Olowolafe, his cooperation right from the conception of this dissertation to its completion was second to none. Special thanks to my future life partner and my colleagues in the master's program especially in Medical Demography unit and all who rendered help in one way or another towards the actualization of this dissertation. My earnest prayer is that God will reward you all bountifully, Amen.

TABLE OF CONTENTS

CHAPTER ONE

Introduction

CHAPTER TWO

Literature Review

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

NDHS	Nigeria Demographic and Health Survey
HP	Heligman Pollard
EA	Enumeration area
NVSS	National Vital Statistics System
HIV	Human Immune Virus
HDSS	Health and Demographic Surveillance System
LT	Life Table

CHAPTER ONE

INTRODUCTION

1.1 . BACKGROUND OF THE STUDY

Under-five mortality remains an issue of public health concern. Global under-five mortality rate in year 2015 was 43 deaths per 1000 live births, representing 5.9 million under five deaths worldwide in year 2015. Sub Saharan Africa is the region with the highest under five mortality rate worldwide (United Nations, 2015). Under-five mortality rate in Sub Saharan Africa in 2015 was 83 deaths per 1000 live births. Thus, sub Saharan Africa is the highest contributor to under-five mortality globally with 49.6 % share in global under-five deaths (United Nations, 2015).

In Nigeria, child mortality remains an issue of public health concern; Infant mortality ($_1q_0$) is the probability that a baby will die before his/her first birthday while Under-5 mortality ($_5q_0$) is the probability of dying between birth and the fifth birthday. Infant and under-five mortality rates recorded in the recent Nigeria Demographic and Health Survey were 69 deaths per1000 live births and 128 deaths per 1000 live births respectively (NPC & ICF Macro, 2014). Previous studies conducted in Nigeria have shown that there are significant spatial differences in infant and under five mortality rates among the geopolitical regions in Nigeria (Aigbe and Zannu, 2012, Adedini et al, 2015)

To solve problems of mortality generally, timely and accurate statistics are required. A study by Verhulst in 2016 showed that the most reliable data source for tracking progress on under-five mortality rate is the vital statistics registration system. Unfortunately, few developing countries have civil registration systems that are complete enough to provide accurate measures of child mortality (Hill and Pebley, 1989). Consequently, several methodologies have been proposed for childhood mortality measurement for countries with limited data and poor data quality. Child mortality rates can be estimated directly from vital statistics registration system, censuses, and health surveys or indirectly, using indirect techniques of demographic measurements (Silva, 2012). One of such techniques known as Heligman pollard model was used in this study.

Demographic models are an attempt to represent demographic processes in the form of a mathematical function or they can be described as a set of functions relating two or more measurable demographic variables (United Nations, 1983). The primary purpose of modeling is simplification that is to reduce a confusing mass of numbers to a few, intelligible basic parameters. The characteristics of a mortality model include; smoothness, parsimony, interpolation, comparability, suitable for forecasting and trends and Analytic manipulation (Congdom 1993 in Mazzuco and Scarpa, 2014).

The Heligman pollard model used in this study is an eight-parameter 'law of mortality', that graduates a set of age-specific probabilities of dying from the standard set of five-year age groups into a set of single-year probabilities of dying which makes it suitable for mortality analysis and forecasting (Rogers and Gard, 1991). The eight parameter Heligman pollard model has three components that reflect the age pattern of mortality in childhood, young adulthood and older ages (Booth and Tickle, 2008). This study uses all the components of the model.
The general formular of the model is

$$qx/px = A^{(x+B)^{c}} + De^{-E(\ln x - \ln F)^{2}} + GH^{x} \qquad (1)$$

The model also has alternative forms which are applied to match the data available for estimation and they lead to improvements in the model fit (Heligman and Pollard, 1980). q_x is the probability that a person aged exactly x will die within one year, p_x= 1 -q_x and A, B, C, D, E, F, G and H are the parameters to be estimated. Each parameter has a demographic interpretation (Heligman and Pollard 1980; McNown and Rogers 1989; Rogers and Gard 1991).

Parameter A represents the level of child mortality and is nearly equal to q_1, parameter B is the difference between age 0 and 1 mortality probabilities, parameter C measures the decline in mortality during childhood that is the rate at which child adapts to its environment. Parameter D represents the level (or height) of the mortality hump, parameter E is inversely related to the width of the mortality hump, parameter F is the location of the mortality hump on the age axis, Parameter G measures Late life mortality, it is the intercept of Gompertz curve at age 0 while parameter H is the slope of Gompertz curve (Sharrow et al, 2013; Heligman and Pollard, 1980).

The geographical focus for this study is the six geopolitical zones in Nigeria, with the aim to estimating the probability of death at childhood ages. The Heligman Pollard model was developed by Heligman and Pollard in 1980 to study the age pattern of mortality and it has been used to model mortality in a variety of contexts. The Heligman Pollard model has been used in the United States of America by Mode and Busby and in Sweden by Hartmann. The Heligman Pollard model is difficult to fit and its parameters are highly correlated thus there is colossal problems of identifying specific parameters (Sharrow et al, 2013). This problem is often solved by using strategies that improve model fits and numerical properties (Jones, 2005). One of these strategies is the Bayesian fit used by Sharrow et al in 2013 and Emilidha and Danardono in 2017.

1.2. STATEMENT OF THE PROBLEM

Sub-Saharan Africa region has the highest under-five mortality rate worldwide and it is the highest contributor to under-five mortality globally with 49.6 % share in global under-five mortality (United Nations, 2015). Half of under-five deaths in the globe occur in Nigeria and four other countries. After India (21%), Nigeria contributes 13% to under-five deaths globally (United Nations, 2014). The most reliable source of data for tracking progress on under-five mortality rate is the vital statistics registration system (Verhulst, 2016). Unfortunately few less-developed countries have civil registration systems that are complete enough to provide accurate measures of child mortality (Hill and Pebley, 1989).

Inaccuracy of census counts and incompleteness of vital registration system are challenges to the estimation of mortality rates in Nigeria. Thus, there is likelihood that the available estimates of childhood mortality in Nigeria could be mix-presented and at times different methodologies which produce conflicting results are applied. This suggests that there is likely to be a gap between childhood mortality estimates available in literature and the true picture of current childhood mortality situation in Nigeria. Since the accurate measurement and estimation of mortality levels, trends, causes, and differentials is a cornerstone of public health (Mathers and Boerma, 2010), this poor statistics hinders progress towards child mortality reduction and general health improvement. Studies also reveal that there are significant spatial differences in infant and under five mortality rates among the geopolitical regions in Nigeria (Aigbe and Zannu, 2012, Adedini et al, 2015).

Mortality information is commonly available and most appropriate in 5 year age groups due to errors in data collection thus there is a gap in knowledge of the probability of death at specific ages ~~(Ibrahim~~ 2008). This informs the need for a more reliable means of mortality estimation in Nigeria in order to obtain more accurate estimates that best describes mortality at childhood ages for each geopolitical zone in the country.

1.3.RESEARCH JUSTIFICATION

The issue of childhood mortality has been over flogged by researchers in Nigeria, but in most of these researches, the univariate, bivariate and multivariate methods of analysis are often used to assess the levels and determinants of childhood mortality (Adedini et al, 2015). The use of the Heligman pollard model for mortality estimation in exploring the age pattern of mortality is yet to be documented in Nigeria. There are several issues underlying data used in derivation of estimates of the under-five mortality rate from Nigeria. The country has abundant data but wide variations in rates and trends between data sources (United Nations, 2014). The disparity in estimates of childhood mortality from different methods necessitates an approach that will represent prevailing and contemporary mortality pattern in Nigeria.

Hartmann concluded that the Heligman Pollard model is the best existing demographic model for estimating mortality at all ages and is an efficient means of generating life table models for use in population projection (Sharrow et al, 2013). In the discussion of the Heligman Pollard model by Kostaki; he concluded that the model provides a satisfactory representation of the age pattern of mortality (Sharrow et al, 2013). The model is most suitable because it engages the use of several parameters. The results of this study shall also contribute to a growing literature on the effective use of the Heligman Pollard model in estimating infant and under-five mortality and mortality through adult ages.

1.4. RESEARCH QUESTIONS

1. What are the levels of infant and under-five mortality across the geopolitical zones in Nigeria?
2. What are the regional estimates of life table functions in Nigeria?
3. What are the Heligman Pollard model estimates of infant and under-five mortality in Nigeria?

1.5.OBJECTIVES OF THE STUDY

1.5.1. GENERAL OBJECTIVE

To estimate regional differentials in under-five mortality in Nigeria, using the Heligman Pollard model.

1.5.2. SPECIFIC OBJECTIVES

1. To determine the level of infant and under-five mortality across the regions in Nigeria.
2. To provide regional estimates of life table functions in Nigeria.
3. To assess the use of Heligman Pollard model for under-five mortality estimation in Nigeria.

CHAPTER TWO
LITERATURE REVIEW

This section is made of three components, the childhood mortality situation globally, childhood mortality situation in sub-Saharan Africa and childhood mortality trends in Nigeria. It also include records of the use of the Heligman Pollard model in different part of the world, sub-Saharan Africa and Nigeria.

2.1. CHILDHOOD MORTALITY SITUATION GLOBALLY

Mortality is the cessation of all biological functions that sustain a living organism while mortality rate, also known as death rate is the proportion of deaths in a population. Mortality is a major factor that influences population reduction. It is one of the 3 major components of demography. Mortality rate can be measured in several ways for various sub units of the population. Child mortality rates are useful indices in measuring the level of child health, socio-economic development and defining the quality of life of people in a population (Adebayo and Fahrmeir, 2002).

Globally, around 7 million under-five deaths were recorded in 2011 (UNICEF, 2012). This estimate reduced to 6·3 million under-five deaths per 1000 live births in 2013 (UNICEF, 2013). Child mortality remains an issue of global concern thus several efforts is put in reducing preventable child deaths globally. Decline in infant and child mortality have been achieved globally over the years, global under-five mortality rate dropped by 53 %, from 91 deaths per 1,000 live births in 1990 to 43 deaths per 1,000 live births in 2015. Over the same period, the annual number of under-five deaths dropped from 12.7 million to 5.9 million (United Nations, 2015). Though progress is being made in reducing child mortality at the global level, Southern Asia and sub Saharan Africa region still require urgent support in reducing child mortality as these areas have the highest burden of child mortality.

Southern Asia has the second highest under-five mortality rate in the world with 1 in 19 children dying before their fifth birthday (United Nations, 2015). The under-five mortality rate in Southern Asia region as at 2015 was 51 deaths per 1,000 live births consequently three in 10 global under-five deaths occur in Southern Asia. The three leading causes of childhood mortality are preterm birth complications, pneumonia, and intra partum-related complications. Reductions in pneumonia, diarrhea, and measles collectively accounted for half of the 3·6 million fewer deaths recorded between 2000 and 2013. Nigeria, India, Democratic Republic of the Congo, Pakistan, and China collectively accounted for half (3.754 million) of global under-five deaths in 2010 (Liu et al, 2012). If present trends continue, it is projected that 4·4 million children younger than 5 years will die in 2030. Also, it is projected that sub-Saharan Africa will have 33% of the child births and 60% of child deaths in 2030, compared with 25% child births and 50% child deaths experienced in 2013 (Liu et al, 2015).

The Relative risk (RR) of mortality is highest in Africa compare to other regions of the world; it is about seven times higher than the levels obtainable in most high-income countries (Patton et al, 2009). The top five causes of this mortality include HIV/AIDS, lower respiratory tract infection, diarrhea infection, malaria and strokes (World Health Organization, 2016). The leading causes of death in Africa mentioned above are aggravated by numerous factors spanning the social, economic and political facets. Poor environmental conditions during periods of political instability also results in massive loss of lives and increase in the number of orphans and vulnerable population.

Sub-Saharan Africa is the region with the highest under-five mortality rate in the world. 1 child in 12 dies before his or her fifth birthday, far higher than the average ratio of 1 death in 147 live births obtainable in high-income countries (United Nations, 2015). Majority of countries with the highest levels of child mortality are located in sub-Saharan Africa. Following the increase in the global average annual rate of decline in under-five mortality from 1.8 percent in 1990 to 3.9 percent in 2015, sub-Saharan Africa also experienced progress in under-five mortality reduction with rates of reduction increasing from 1.6 percent in 1990 to 4.1 percent in 2015 (United Nations, 2015).

Despite this progress, sub-Saharan Africa region still has the highest child mortality rate of 92 deaths per 1,000 live births. The fertility rate in sub Saharan Africa is the highest among regions of the world with a rate of 4.7 children per woman (United Nations, 2015) thus the region has a very high population, large number of dependents and high levels of poverty. A comprehensive effort is thus needed to provide the necessary services to improve child survival (United Nations, 2015). Considering the growing number of births and child populations in the Sub-Saharan region, Liu et al. (2015) predicted that the number of under-five children in sub-Saharan Africa will increase by an extra 26–57 million, from 157 million in 2015 to between 183 and 214 million in 2030. This implies more child deaths if the current trends of population growth are not averted. It is also projected that by 2050 close to 40 percent of all births will take place in sub-Saharan Africa, and 37 percent of children under age five will live in this region. Thus, the number of under-five deaths could increase in the region (Liu et al, 2015).

High global childhood mortality rate has been an issue of public health concern. As a result, several studies have been carried out to unveil the situation, study trends and find lasting and reliable solutions to the problem of child mortality. To solve problems of mortality generally, timely and accurate statistics are required. The most reliable data source for tracking progress on under-five mortality rate is the vital statistics registration system (Verhulst, 2016). Often times these statistics are only available in developed countries with working vital statistics registration systems and regularly updated population registers. This poses challenges in majority of the less developed countries where this system does not exist or is incomplete. Good quality data are not readily available consequently there is dependence on demographic and health survey data.

With the availability of survey data, it becomes easier to model mortality pattern in countries where quality data are lacking. Different mathematical models have been designed for this purpose including the use of model life tables. Heligman Pollard model is one of these methodologies. The Heligman pollard model is a single expression that describes the probability of death for all ages (Ibrahim, 2008). The model was proposed by Heligman and Pollard in 1980, it is a law of mortality which was fit to post-war Australian national mortality data (Heligman and Pollard, 1980). The Heligman Pollard model is an eight parameter mortality model encompassing the entire lifetime of a human life (Jos, 2014). The idea behind the Heligman pollard model is to decompose the odds that a person of age (x) will die before reaching age $(x+1)$ (Dellaportas et al, 2001).

The basic curve of the model is

$$qx/px = A^{(x+B)^C} + De^{-E(\ln x-\ln F)^2} + GH^x \qquad (1)$$

Where q_x is the probability of dying within one year for a person at exact age x (q_x only take values between 0 and 1).$p_x$is the probability of surviving within 1 year for a person at exact age x given as$p_x = (1 - q_x)$. The model contains three terms and eight parameters (A,B,C,D,E,F,G,H) all of which has demographic interpretations (Heligman and Pollard, 1980). The parameters do not only describe the level but also the shape and location of mortality (Sharrow et al, 2013). The curve is continuous and applies across all age range ($0 \leq x \leq \infty$) and is flexible enough to fit various patterns of mortality obtainable in different populations. The use of the ratio q_x/p_xon the left-hand side of the equation has the advantage that q_x must lie between 0 and 1 for all x, and it improves the fit at older ages (Heligman and Pollard, 1980).

The Heligman Pollard model decomposes the age pattern of mortality into three terms, each with a small number of parameters to control it. Three parameters (A, B & C) describe child mortality, Parameters D, E & F describe a very flexible 'accident' hump typically occurring in young adulthood and two parameters (G & H) describe mortality at older ages (Sharrow et al, 2013). The first term which is a rapidly declining exponential reflects the fall in mortality during the early childhood years as the child adapts to its new environment and gains immunity. Parameter A, which is approximately equal to q1, measures the level of mortality, parameter B is an age displacement to account for infant mortality. B measures the location of infant mortality. Parameter C measures the rate of mortality decline in childhood that is the rate at which a child adapts to its environment. The higher the value of C, the faster mortality declines with increasing age (Heligman and Pollard, 1980).

The second term of the Heligman Pollard model is the accident term; it consists of parameters D, E and F. It reflects accident mortality for males and accident plus maternal mortality for the females. This implies additional mortality superimposed on the 'natural curve of mortality'. The 'accident hump' is attainable in every population, and appears either as a distinct hump in the mortality curve or a flattening out of the mortality rates, usually located between ages 10 and 40. Parameters D indicate the severity, E represents the spread and F indicates location. The third term in the model is the Gompertz exponential, which reflects the near geometric rise in mortality at the adult ages, and it represents senescent mortality. It has two parameters, G and H. The parameter G represents the base level of senescent mortality while parameter H reflects the rate of increase of that mortality.

The three components of mortality and their contribution to total mortality are illustrated graphically in the Figure below using Australian national mortality 1970- 1972 (males).

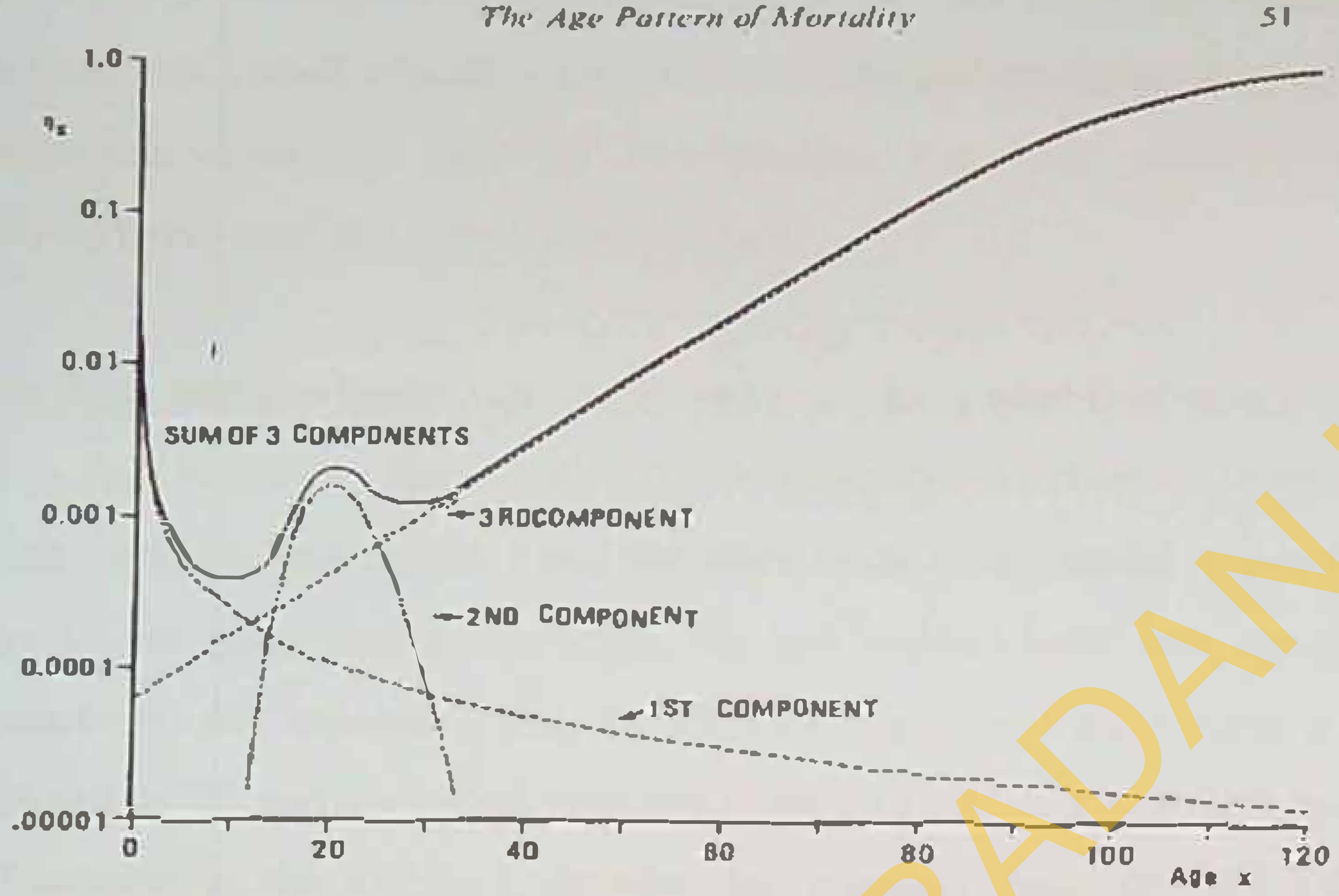

Figure 2.1: The graduated q_x curve and its three components: Australian national mortality, 1970-1972 males (Copied from Heligman and Pollard, 1980).

In Australia, the Heligman Pollard model was used to graduate post-war national mortality. The data used for the graduation were number of deaths by age and sex for the three-year periods (1946-1948, 1960-1962, and 1970-1972) and the mid-year census populations by age and sex for 1947, 1961, and 1971. Central mortality rates by age for each sex were calculated as

$$m_x = /3P_x$$

$\theta_x$represents the number of deaths during the three-year period for persons aged and P_x is the mid-year census population for persons aged x. The central mortality rates were transformed to q_x values by the classical formula

$$q_x = 2m_x/(2 + m_x)$$

Parameters A,B,C,...,H were estimated by applying the least squares methods using Gauss-Newton iteration. The function minimized was

$$S^2 = \sum_{x=0}^{85} (\frac{qx}{qx} - 1.0)^2$$

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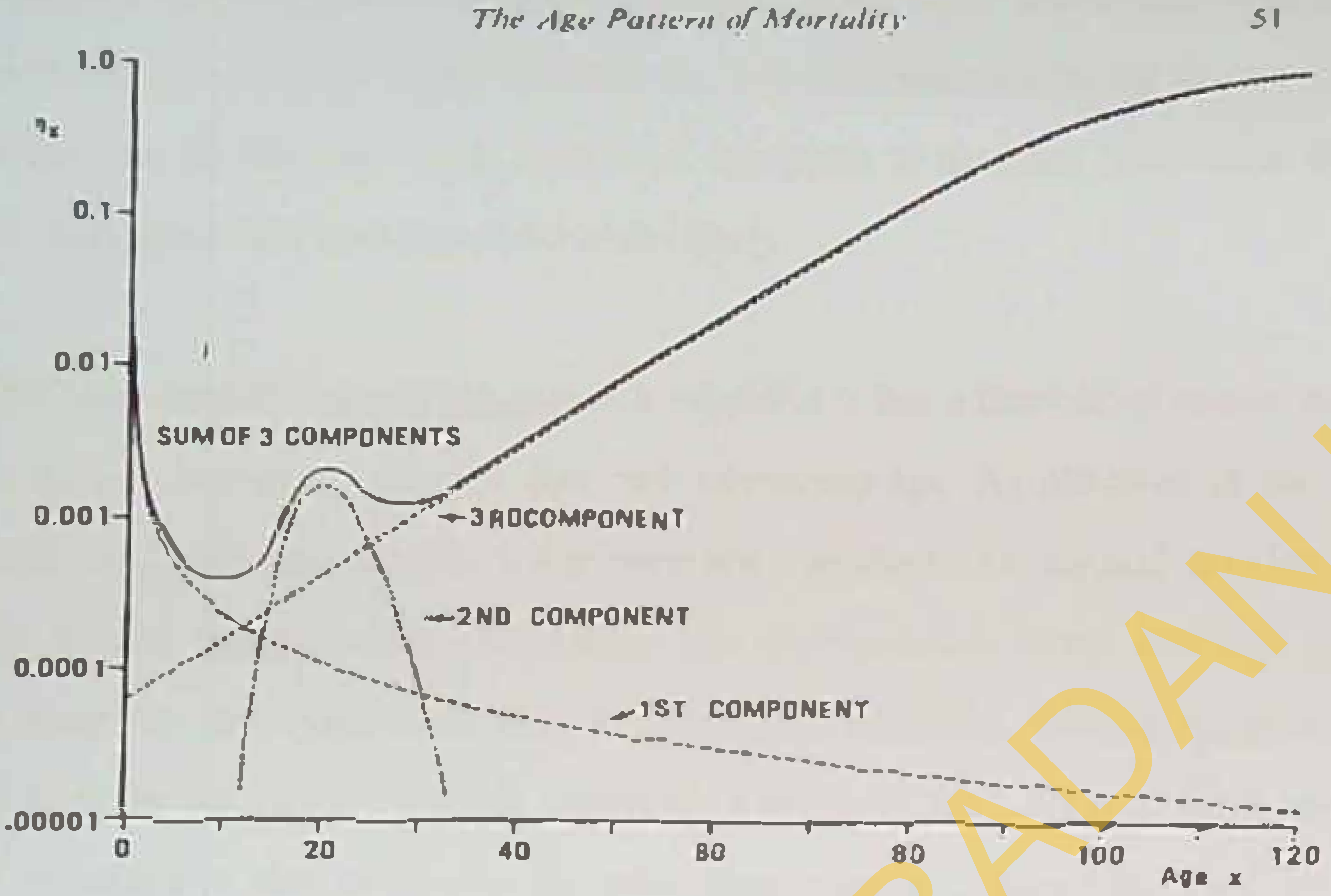

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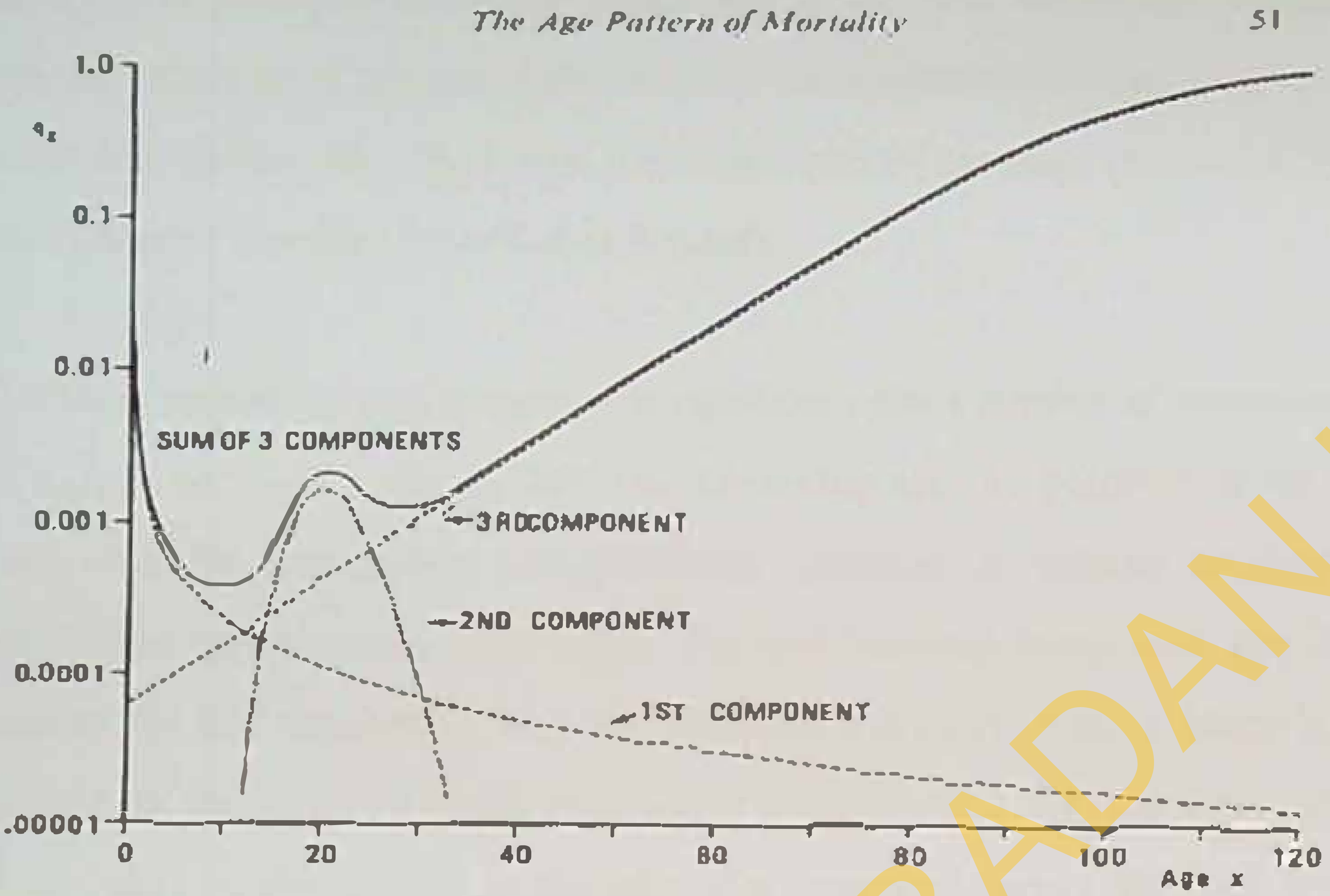

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Parameters A,B,C,...,H were estimated by applying the least squares methods using Gauss-Newton iteration. The function minimized was

$$S^2 = \sum_{x=0}^{85} (\frac{qx}{qx} - 1.0)^2$$

whereq_x is the fitted value at age $x$and q_x is the observed mortality rate.

The graduated mortality probabilities provided adequate representations of the age patterns of mortality in Australia in all six cases (that is for both males and females within the three periods). Also, small amount of curvature, not accounted for by the Gompertz term, was evident in the data for the older adult ages. Two variations of the basic graduation formula to deal with this curvature were also presented in the study.

The basic mortality curve suggested in equation 1 has a number of variations; from equation 1, $\ln(q_x/p_x)$ becomes a straight line with advancing age. As observed in the Australian females 1946-1948, the least-squares fitting procedure produced an unusual 'accident hump' centered at age 53 and spread over a wide range. The true 'accident hump' near age 20 was almost non-existent for this experience, thus the computer algorithm fitted a hump at the older ages to account for the curvature which remained in the $\ln(q_x/p_x)$ curve at those ages. A small amount of curvature is also evident in the other data examined, hence the need for a variation of the equation (1) which addressed the problem.

This led to the mortality curve (1a) which is almost indistinguishable from the first equation.

$$q_x = A^{(x+B)C} + De^{-E(lnx-lnF)^{\wedge}2} + GH^x / 1 + GH^x \qquad (1a)$$

Equations 2 and 3 were also considered because of the residual curvature evident in the data examined.

$$q_x = A^{(x+B)^{\wedge}c} + De^{-E(lnx-lnF)2} + GH^x / (1 + KGH^x) \qquad (2)$$

$$q_x = A^{(x+B)^{\wedge}c} + De^{-E(lnx-lnF)2} + GH^{x^K} / (1 + GH^{x^K})$$

The variations lead to improvements in the fit, especially at the older ages. Heligman and Pollard concluded that the model describes the age pattern of mortality adequately for a variety of experiences. The curve gave an adequate representation of post-war Australian mortality for males and females and the curve itself might possibly be used as a base for a model life table system (Heligman and Pollard, 1980).

In the United States, the late life component of the Heligman pollard model was used to smooth combined death rates at ages 66 to 100 years, while preparing the 1999 to 2001 decennial life tables (Wei et al, 2008). Data used in the study include population data by age at census, Medicare data for deaths and population for ages 66 years and over, deaths in a 3-year period classified by age at death, extracted from National Vital Statistics System (NVSS) and births for each of the years from 1997–2001. The Heligman pollard formula used in the study was

$$\frac{qx}{1-qx} = A^{(x+B)^C} + D\exp[-E(logx - logF)^2] + GH^x$$

The third component the Heligman-Pollard model was found to provide a better estimate of mortality patterns at the older ages than the linearized k_x. The Heligman pollard non-linear smoothing procedures unlike the straight line method provided a more flexible and robust fit of the observed data and the mortality rates predicted appeared more reasonable.

The q_x was fitted with the model:

$$\frac{qx}{1-qx} = GH^x$$

The model was estimated with the SAS nonlinear weighted least squares procedures. The Heligman pollard non-linear smoothing procedures unlike the straight line provided a more flexible and robust fit of the observed data and the mortality rates predicted appeared more reasonable (Wei et al, 2008).

Studying the efficiency of the Heligman pollard model in relation to 3 other models; the Siler model, Mode and Busby model and Mode-Jacobson model, Gage and Mode in 1993 carried out the research to determine if models that incorporate accident hump represent the age pattern of human mortality more efficiently than simple model like the Siler model. This test was carried out by comparing the goodness of fit of the respective models. Independently, the Heligman pollard model fitted 4 life tables slightly better than the Siler model fits and the Siler model significantly fitted 2 life tables than the Heligman pollard model. They also stated that the Heligman pollard model fitted perfectly at ages 1 to 50 and fitted poorly at older ages (Gage and Mode, 1993).

In a study of mortality among Malaysian males and females using empirical data sets of Malaysia population, the abridged life tables for the Malaysian population in year 1991 - 2000 for both males and females were collected. The Heligman Pollard model was used to estimate one year probability of dying from the five year probabilities given in the abridged life table. The Matrix Laboratory Version 7.0 software was used to fit the model. The mathematical function of the model used was

$$\frac{qx}{px} = A^{(x+B)^C} + D * \exp(-E\,(\ln(\frac{x}{F}))^2) + GH^x$$

Where q_x is the probability that an individual who has reached age $x$will die before reaching age $x+1$, $p_x = 1 - q_x$and A;B;C;....;H are the positive parameters to be estimated. As part of the expansion process, the parameters of the Heligman and Pollard model were estimated first by minimizing the sum of squares using the equation

$$S^2 = \sum_x (\frac{nqx}{nqx} - 1)^2$$

Since the purpose of the study is to analyze mortality rate for persons aged 10 years and above, only the second and third term of the model was utilized.

$$\frac{qx}{px} = D * \exp(-E(\ln\left(\frac{x}{F}\right))^2) + GH^x$$

Thus only five parameters of the model (D;E; F;G and H:) was utilized.

The first step was obtaining the abridged n$q_x$values which were given in the abridged life tables and fitting the values to equation the equation above. The Matrix Laboratory Version 7.0 software was then used to solve the nonlinear equations. By inserting these estimated values of the parameters into the equation, the one year probabilities of dying that is $q_x$was estimated. Thus, the author concluded the Heligman Pollard model is the best existing demographic model of mortality at all ages and is an efficient means of generating life tables model, for example for use of population projection as the model provides quite a satisfactory representation of the age pattern of mortality (Ibrahim 2008).

The Heligman pollard model was used by Ozeki in 2005, to fit eighteen Japan Life tables from 1891 to 2000. The results were used to project the Japan Life Table for 2025 (Ozeki, 2005, in Jos, 2014). Jos, I. B estimated the parameters of Philippine, Malaysia, Singapore and Thailand life tables adopting the procedure suggested by Ozeki

in his study of Japanese population in 2005. The Heligman pollard formula applied was

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

where A, B, C, D, E, F, G, H are the model parameters, x represents age, and $\mu(x)$ is the force of mortality. The estimates of the parameters were obtained by minimizing the sum of squares using the equation:

$$s = \sum_{x=0}^{\omega} (\frac{qx}{qx} - 1)^2$$

q_x represents the probability that a person aged x will die on or before attaining age x+1 for the observed data. The limiting age of the table was denoted by ω. The solver add-in of Microsoft Excel was used to determine the estimates and graph of log q_x given by the model and the observed data was plotted for the four countries.

Emilidha and Danardono in 2017, Modeled hospital mortality data using the Heligman-Pollard model with R HPBayes. The number of patients who died at age x, (d_x) and the total number of patients alive at that age (l_x), (both male and female patients) was drawn from the in patient records during the period of 2010-2014 in a general hospital in Sragen Java, Indonesia and were used to model the hospital mortality pattern across the whole life span (0-103 years) using the HP bayes. The Heligman Pollard formula used in the study was:

$$\frac{qx}{1 - qx} = A^{(x+B)^C} + D\exp[-E\{\log(\frac{x}{F})\}^2] + GH^x$$

Where q_x is the probability of dying within 1 year for a life aged x, and A, B, C ….., H are parameters to be estimated. $q_x$is constructed by adding three models representing child, early adult and adult mortality. The Bayesian Melding with Incremental Mixture Importance Sampling which has been implemented in the R library HPbayes were used to estimate the HP parameters given the hospital mortality data. The hospital mortality rate is similar to the general Indonesian mortality rate. The study found that the pattern of mortality among patients who are children is similar to the mortality pattern in the general population while mortality pattern in the early adult and adult ages is higher than what is attainable in the general population. The study concluded that and the risk ratio and mortality pattern for male patients is higher than female patients.

Thatcher et al, 2001 studied the force of mortality at Ages 80 to 120 matched different mathematical models of the force of mortality at high ages and attempts to use the best performing models to draw conclusions about mortality at 120 years. This study was based on the Archive of Population Data on Ageing held at the University of Odense, which contains all the available official statistics on deaths at ages 80 and over for 30 countries since 1960. Six models were selected for comparison, the logistic model, Kannisto model and a quadratic model, the Gompertz and Weibull models were weak since they fall short of efficiently estimating mortality at high ages. The Heligman-Pollard model was also predicted to overshoot at high ages. Data were collected and models were fit to each country's data over the entire age range 80 years and over, graphical results were also presented that confirm the above.

Njenga and Sherris used Bayesian vector autoregressive model to estimate the parameters of the Heligman Pollard model and fit the model to Australian data in 2011. Data for the study was obtained from Australian population data in the human mortality data base. The Heligman Pollard curve applied in the study is:

$$qx(\theta_t) = q_{x,t} = At^{(x+B_t)C_t} + D_t\exp[-E_t(\log\{\frac{x}{Ft}\})^2] + \frac{G_tH_t^x}{1+G_tH_t^x}$$

The result of the study showed a steady decline in mortality of children at age one and mortality in adult males was consistently higher than mortality in adult females within the study period.

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Peristera and Kostaki in 2005 evaluated the performance of kernel regression estimators used in graduation of mortality data using data for France, Japan and Sweden. They compared 3 kernel regression estimators; Nadaraya-Watson, Gasser-Muller and kernel weighted local linear estimators with the Heligman-Pollard model and its nine-parameter version in the context of mortality graduation. A total of 18 empirical data sets were used in the study. The Heligman pollard model and its variant used is

$$qx/px = A^{(x+B)^c} + Dexp(-E(lnx - lnF)^2) + GH^x$$

$$\frac{q_x}{p_x} = A^{(x+B)^C} + Dexp(-E_1(\log\left(\frac{x}{F}\right))^2) + GH^x, \qquad \text{for } x <= F$$

$$\frac{q_x}{p_x} = A^{(x+B)^C} + Dexp(-E_2(\log\left(\frac{x}{F}\right))^2) + GH^x, \qquad \text{for } x > F$$

Regarding the behavior of these estimators in comparison Pollard eight and nine-parameter models, the Muller estimate was superior at older adult ages, and offered suitable terms of both smoothness and fit. In most cases, the parametric smoothed the data especially at ages 0 to 30, but in data sets with accident hump. The 8 parameter version of Heligman Pollard does not adequately fit observed rates; this problem was addressed using the 9 parameter version of Heligman Pollard.

According to Sharrow et al, 2013, the Heligman Pollard model has been used in the United States of America by Mode and Busby and in Sweden by Hartmann. The Heligman Pollard model is difficult to fit and its parameters are highly correlated thus there is colossal problems of identifying specific parameters (Sharrow et al, 2013). This problem is often solved by using strategies that improve model fits and numerical properties (Jones, 2005). One of these strategies is the Bayesian fit used by Sharrow et al in 2013. Ability to produces smooth curves, ability to interpolate and to extrapolate, possibility of formal manipulation, Parsimony, possession of interpretable parameters whose values can be compared easily, ability to easily capture and reflect trends and mediate comparisons are the advantages of the Heligman pollard model (Dellaportas, 2001).

2.2. CHILDHOOD MORTALITY SITUATION IN SUBSAHARAN AFRICA

Under-5 mortality (5q0) is the probability of dying between birth and the fifth birthday (NPC & ICF Macro, 2014). About half of child deaths occur in Sub-Saharan Africa. Sub-Saharan Africa is a major contributor to child mortality statistic as more than two in five under-five deaths occur in the region (Black et al, 2003) Child mortality is a useful index of a nation's health conditions and as guide for structuring public health programs. Child Mortality Rate is highest in low-income countries, such as Sub-Saharan African countries since it is interwoven to social, cultural, economic, physiological and other factors. The high rate of infant and child mortality in the sub Saharan region shows a low development of health program in the nation. Social and economic determinants of infant and child mortality function through a common set of demographic mechanisms or proximate determinants to influence mortality (Mosley and Chen, 1984).

According to World Health Organization report in 2011, nearly half of global childhood mortality (42%) occur in sub Saharan Africa with about 25,000 under-five deaths occurring daily in South Asia and sub-Saharan Africa. The probability of death varies at different stages of life within the under-five age group, 60% of under-five mortality occurs at infancy, with the highest vulnerability at the first 24 hours of life, followed by the first week and the first month (Marx et al, 2005 in Adetoro and Amoo, 2014) Child mortality and malnutrition are vital socio-economic and demographic problems in sub-Saharan African countries, and they have great influence on development of the region (Adebayo, F. 2002). Some determinants of child mortality in sub Saharan Africa include wealth index and maternal education. Children born into poor households, experience highest levels of mortality compare to those born into rich households (Adetoro and Amoo, 2014). Poor hygienic conditions is a major driver of poor child health and survival, educated mothers are more likely to ensure a healthy environment, nutritious food and better living conditions for their children than their uneducated counterparts (Adetoro and Amoo, 2014) Literate mothers tends to be healthier and are more likely to experience lower mortality among their children at all ages (Pandey, 2009).

Reduction of child mortality is of vital in many populations and is the fourth of the United Nations' Millennium Development Goals (MDG4). The MDG4 is a drive to cut down the level of preventable child deaths in the participating countries. Through the efforts of government and well-meaning donor agencies, Sub-Saharan Africa has recorded a decline in the under-five mortality rate, with the average annual rate of reduction increasing from 0.8% in 1990–1995 to 4.2 % in 2005–2013. Despite this progress, the region still has the highest child mortality rate of 92 deaths per 1,000 live births, more than 15 times the average attainable in developed regions of the globe. It is projected that by 2050 close to 40% of all births will take place in sub-Saharan Africa and 37% of children under age five will dwell in this region. Thus, the under-five mortality rates could stagnate or increase without more progress in the region. The 2002 UHES in Uzbekistan presents that differentials in infant and child mortality are instigated by socioeconomic characteristics, place of residence, mothers' level of education, ethnicity and length of the preceding birth interval (Sullivan and Tureeva, 2002)

Estimates of probabilities of dying between exact ages, for example x and x+n, are good measures of child mortality situation in any given population (Pebley and Hill, 1989) The Heligman Pollard model is a suitable model for estimation of age specific probability of death. One of the occasions where the model was used in sub-Saharan Africa is the study by Sharrow et al in 2013. He used the Heligman Pollard model to investigate the sex-age-specific changes in mortality in a prospectively monitored rural population in north east South Africa. The data used in the study was obtained from the Agincourt health and demographic surveillance system (HDSS). Time-sex-age specific counts of deaths and person years for 1994-2007, aggregated into 4 periods were used.The goal of the study was to develop new methods that can be useful in fitting the Heligman Pollard eight-parameter model of age-specific mortality. Thus the Bayesian estimation method was adapted to estimate the parameters of the Heligman Pollard model. The Heligman Pollard formular used in the study is:

$$q_x = A^{(x+B)^C} + D * e^{-E(\ln(x)-\ln(F))^2} + \frac{GH^x}{1+GH^x}$$

Where x represents age, q_x is the probability of death at age x, and A;B;C; : : : ;H are eight flexible parameters that govern the shape of the mortality curve. Parameter A,B and C all have domains between 0 and 1. He found that there was vivid increase in child mortality due to HIV and he was able to obtain the age sex specific pattern of increases in mortality.

Hartmann in his study concluded that the Heligman Pollard model is the best existing demographic model for estimating mortality at all ages and is an efficient means of generating life table models for use in population projection. In the discussion of the Heligman Pollard model by Kostaki, he concluded that the model provides a satisfactory representation of the age pattern of mortality (Ibrahim, 2008). Thus, the Heligman pollard model for mortality estimation is a better model for assessing the true situation of mortality in a population.

2.3. CHILDHOOD MORTALITY TRENDS IN NIGERIA

Nigeria, the most populous country in Africa, is among countries with high levels of Under-Five Mortality in the globe. The under-five mortality rate in Nigeria is 128 deaths per 1000 live births in the year 2013 (NPC & ICF Macro, 2013). Nigeria has the highest reported number of under-5 deaths in sub Saharan Africa (Ezeh et al, 2015). Nigeria is a country with diverse religions, ethnic groups, ecology, believes and values. Thus, there are variations in exposures and health outcomes in various regions of the country. There are substantial regional disparities in under-five mortality in Nigeria. Community-level characteristics explain regional variations in child mortality, while individual-level factors are responsible for the regional variations observed in infant mortality (Adedini et al, 2015) The northern region of the country which is marked with low maternal education and poor standard of living has the highest levels of under-five mortality in the country. Thus, Under-five mortality rates ranges from 90 per 1000 live births in the South West to 185 per 1000 live births in the North West (NPC & ICF Macro, 2014). Nigeria is the sub Saharan Africa country that contribute highest (13%) to global under-five mortality rate and together with India (21%), Nigeria accounts for more than a third of all under-five deaths worldwide (UNICEF, 2014).

A number of factors are responsible for the high levels of under-five mortality observed in the country, including maternal and childhood factors, community and individual-level factors as identified by Adedini et al, 2015. Demographic characteristics of both mothers and children are major drivers of child survival (NPC & ICF Macro, 2014). Size of the child at birth, preceding birth interval, prenatal care provider, place of residence, maternal level of education, wealth index, media exposure and housing material type also influence child survival rates (Adebowale et al, 2013) Poverty, malaria, postnatal care and breastfeeding were the major determinants of child mortality in Oyo state in a study conducted by Bello and Joseph in 2014; HIV only increased chances of mortality. Maternal education, mothers occupation, wealth index, age at first birth and usual of place of residence have significant impact on child mortality in Nigeria (Adetoro and Amoo, 2014).

Nigeria is faced with several health challenges irrespective of the advances in medical technology and efforts of medical experts (NPC & ICF Macro, 2009). These include high rates of under-five mortality (128 deaths per 1000 live births), high levels of teenage pregnancy (23%

of young women aged 15–19 have begun child bearing), poor utilization of maternal health care facilities (Only 38% of deliveries are attended by a skilled birth attendants) poor pregnancy outcomes (such as stillbirth, spontaneous abortion and low birth weight), poor survival chances for the newborn and high unmet need for family planning (16% of currently married women have an unmet need for contraception in the country) (NPC & ICF Macro, 2014).

Child mortality is a core indicator for measuring the level of child health and well-being in all nations (United Nations, 2015). Childhood mortality remains an issue of concern in every population thus several studies on the topic and relentless efforts of Health professionals and policy makers to combat the increasing childhood mortality rates. The logical strategies to reduce child mortality by two-thirds among children under the age of 5 years between the year 2000 and 2015, known as the Millennium development goals was adopted by 195 countries but only 62 countries met the target of a two-thirds reduction in Under-five Mortality rates (United Nations, 2014). Nigeria and many other developing countries did not meet this goal. The United Nations in 2015 adopted the Sustainable Development Goals in a bid to fulfill the promise of safeguarding the lives of children and ending preventable deaths of newborns and under-fives by the year 2030 (WHO, 2016).

Adequate information about child mortality became available with the emergence of civil registration systems for recording births and deaths in populations. These systems first developed in north-western Europe and spread to other countries of the world. Civil registration systems are not common in developing countries hence there is high dependence on survey data for mortality estimation. The Nigeria demographic and health survey (NDHS 2013), used in this study is one of such surveys; it is a national sample survey that provides up-to-date information on background characteristics of the respondents. The target groups were women and men age 15-49 in randomly selected households across Nigeria. information is collected on fertility levels, marriage, fertility preferences, awareness and the use of family planning methods, child feeding practices, nutritional status of women and children, adult and childhood mortality, awareness and attitudes regarding HIV/AIDS, female genital mutilation, and domestic violence (NPC and ICF Macro.2013)

CHAPTER THREE

METHODOLOGY

3.1 DESCRIPTION OF THE STUDY AREA

Nigeria lies on the west coast of Africa between latitudes 4°16' and 13°53' north and longitudes 2°40'and14°41' east. It occupies approximately 923,768 square kilometers of land stretching from the Gulf of Guinea on the Atlantic coast in the south to the fringes of the Sahara Desert in the north. The territorial boundaries are defined by the republics of Niger and Chad in the north, the Republic of Cameroon on the east, and the Republic of Benin on the west. Nigeria is the most populous country in Africa and the 14th largest in land mass. According to the 2006 population and housing census, Nigerian's population is 140,431,790 and the population of the under-five children is 16.1% of the total population (NPC & ICF Macro, 2009). There are 71,345,488 males and 69,086, 302 females with sex ratio of 1.03 and 28,197,085 regular households. Nigeria is made up of 36 states and a federal capital territory; it has 6 geo-political zones and 3 major ethnic groups.

The North-West and North-East regions of the country have the highest prevalence of child mortality with about 105 and 90 deaths per 1000 live births respectively. South-West has the lowest child mortality rates of 31 deaths per 1000 live births (NPC & ICF Macro, 2014). The estimated life expectancy in Nigeria for the year 2017 is 54.07 years. The total fertility rate is 5.5 (NPC & ICF Macro, 2014) Infant and under-5 mortality rates as reported in the 2013 Nigeria Demographic and Health Survey were 69 and 128 deaths per 1,000 live births, respectively.

3.2 STUDY POPULATION

The 2013 NDHS was a nationally representative survey that covered the entire population residing in non-institutional dwelling units of the country. The survey used as a sampling frame, the list of enumeration areas (EAs) prepared for the 2006 Population Census of the Federal Republic of Nigeria, provided by the National Population Commission. The 2013 NDHS is the seventh DHS in Nigeria, following those implemented in 1986, 1990, 1999, 2003, 2008 and 2010. A nationally representative sample of 40,320 households from 904 primary sampling units (PSUs) was selected. All women age 15-49 who were usual members of the selected households or who spent the night before the surveys in the selected households were eligible for individual interviews. In addition to the female survey, a male survey was conducted at the same time in every second household selected for the female survey. In these households, all men age 15-49 who were usual members of the selected households or spent the night before the survey in the selected households were eligible for individual interviews.

3.3 STUDY DESIGN

The study used 2013 Nigeria Demographic and Health Survey which was a cross-sectional study.

3.4 SAMPLING TECHNIQUE

The 2013 NDHS sample was designed to provide population and health indicators estimates at the national, zone and state levels. The sample design allowed for specific indicators to be computed for each of the six zones, the 36 states and the federal capital territory, Abuja. Administratively, Nigeria is divided into states, each state is subdivided into local government areas, and each local government area is divided into localities. In addition to these administrative units, during the 2006 population census, each locality was subdivided into census enumeration areas. The primary sampling unit (PSU), referred to as a cluster in the 2013 NDHS, is defined on the basis of EAs from the 2006 EA census frame. The 2013 NDHS sample was selected using a stratified three-stage cluster design consisting of 904 clusters, 372 in urban areas and 532 in rural areas. A complete listing of households and a mapping exercise were carried out for each cluster from December 2012 to January 2013, with the resulting list of households serving as the sampling frame for the selection of households. All regular households were listed. The NPC listing enumerators were trained to use Global positioning System (GPS) receivers to calculate the coordinates of the 2013 NDHS sample clusters.

3.5 DATA MANAGEMENT AND ANALYSIS

SPSS Version 20 was used to analyze the data extracted from the Nigeria Demographic Health Survey 2013 data set (women data with code NGIR6AFL). The variables analyzed were total children ever born (variable 201), number of living children (variable 218) for 5 year age group of women (variable 013), region of residence (variable 024), siblings age at death (variable mm7$01 and current age of sibling (variable mm3$01). These data were obtained from 2013 Nigeria Demographic and Health Survey and were used in estimating childhood and adult mortality using Brass and siblings method respectively. The Heligman Pollard model for mortality estimation was used to estimate the probability of death for the six geopolitical zones in Nigeria. Graphs were constructed with Microsoft excel and exported to Microsoft word, the software used for writing the report.

3.6 CHILDHOOD MORTALITY ESTIMATION

The estimate of under-five mortality was derived by indirect method. The procedure in Manual X was adopted (United Nations, 1983).

The rationale of the Brass's method: the proportion children dead for a given age group of mother depends on the lengths of time since the children were born

Step 1: Tabulate the mean children born per woman, and proportion of children dead for given age of mother.

Step 2: Identify adjustment factors by which the proportions of children dead had to be multiplied to give life table function $q(r)$ (probability of dying). Note: This adjustment factor was developed by Trussel in 1979. The adjustment factor K_1 is given as:

$$K_i = a_i + b_i \cdot P_1/P_2 + c_i \cdot P_2/P_3$$

Where a_i, b_i and c_i are coefficients given by Trussel;

(P_1/P_2) is the ratio of mean children ever born per women in the 15-19 and 20-24 years age group;

(P_2/P_3) is the ratio of mean children ever born per women in the 20-24 and 25-29 years age group

Step 3: Multiply the proportion of children dead by identified adjustment factors to give life table function probability of dying.

That is: $q(x)' = D_i * K_i$

Where $q(x)$ is probability of dying between birth and exact age x, D_i is proportion of children dead, and K_i is adjustment factors.

3.7 ADULT MORTALITY ESTIMATES DERIVED FROM INFORMATION ON SURVIVAL OF SIBLINGS

Timeus et al, 1997 in Moultrie, T. et al, 2013 described the relationship between the proportions of surviving siblings and life table probabilities of surviving from age 15. These model relationships turn out to be very strong and are effectively the same for males and females. For both males and females, the relationship can be expressed as:

$l_x/l_{15} = a(x) + b(x)S(x\text{-}5,5)$

Where $S(x\text{-}5,5)$ is the proportion of brothers (or sisters) who, having survived to age 15, are still alive among those reported by respondents aged $(x\text{-}5,x)$.

Procedure

Column 1: Age group of the respondents

Column 2: Respondent's sibling alive at age 15

Column 3: Siblings dead

Column 4: Proportion of siblings who survived to age 15 and were still alive at the time of interview by given age group of respondents (${}_5S_{n-5,}$).

Column 5: Upper limit of each successive age group of respondents

Column 6: Estimated adult mortality by the equation: $l_n/l_{15} = a(n) + b(n))\,{}_5S_{n-5}$

Where l_n/l_{15} is the probability of survival to age n, given survival to age 15; a(n) & b(n) are estimation coefficients given by Timeus and others (1997); and ${}_5S_{n-5}$ is the proportion of siblings who survived to their 15th birthday and were still alive at the time of interview.

3.8 LINKING CHILDHOOD AND ADULT MORTALITY ESTIMATES

The estimate of adult mortality obtained above is in form of conditional survivorship probability, but we are interested in the unconditional probabilities, since they define a conventional life table. It is useful, therefore, to have some procedure for linking conditional probabilities of adult survivorship, of the form l(x)/l(y), with other information about survivorship, particularly that in childhood. Not only would such a procedure make possible the derivation of a complete life table, but it would also incorporate some element of smoothing over the range of survivorship estimates available. In the two-parameter logit life-table system, any pair of survivorship probabilities, one from birth and another conditional on attaining a certain age, uniquely determine values of the parameters α and β defining a life table in the system. However, because one of the probabilities is conditional, the values of these parameters have to be estimated iteratively, as there is no way of solving for them algebraically. The logit system which provides a convenient basis for such a procedure, and an iterative process that also introduces a powerful smoothing component is described below:

PROCEDURE

Step I: initial estimate of parameter alpha; given an estimate of $l_{(z)}$ such as $l_{(2)}$ for children, the initial estimate of parameter α is obtained as

$$\alpha_l = \log it\ l_2 - \log it\ l_{s2}$$

Assuming that β = 1.0.

Step 2: Given the α_1 estimated in step 1 and still assuming that β = 1.0. A first estimate of this survivorship probability, $l_{(y)}$ denoted by $l_{1(y)}$, is obtained from equation:

$$l_{1(y)} = \frac{1}{1+e^{2(\alpha+B\log it(lsx))}}$$

Step 3: The initial approximation to $l_{(y)}$ $l_{1(y)}$, is used to calculate initial estimates of the survivorship probabilities from birth, $l_{(x)}$, for each value of x from the observed ratios $l_{(x)}/l_{(y)}$:

$$l_{1(x)} = l_{1y}.\ \frac{lx}{ly}$$

Step 4: Modified estimate of parameter β can be obtained as follows:

$$\beta = \frac{\log it(lx) - \log it(ly)}{\log it(lsx) - \log it(lsy)}$$

A single estimate of β can then be obtained by averaging the β(x) values. It is often the case that the values of β(x) vary sharply with x, and it may be decided that a best estimate of β can be obtained by averaging the β(x) values after excluding obvious outliers, such as the highest and lowest values.

Step 5: A second estimate of α, denoted by α_2, is obtained by repeating step 1, but now using the estimate of β_2 obtained in step 4 instead of the first assumed value of β = 1.0. Thus,

$$\alpha_2 = \log it\ l_2 - \beta_2 \log it\ l_{s2}$$

Step 6: Second estimate of survivorship probability used as denominator. The new value of α, denoted by α_2 and the second approximation to β, denoted by β_2, are now used to obtain a revised value of l_y, and denoted by l_{2y}, as follows:

$$l_{2(y)} = \frac{1}{1+e^{2(\alpha+B\log it(lsx))}}$$

Step 7: The iterative procedure continues, but an approximation can be obtained by:

$$\beta_3 = 1.5\,\beta_2 - 0.5$$

Then, instead of substituting the value of β in step 5, a more rapid convergence can be achieved by substituting β_3 instead.

Final step: Calculation of fitted life table. Once final estimates of α and β have been arrived at, the estimated $l^*(x)$ function of the fitted life table can be calculated using equation:

$$l_x = \frac{1}{1+e^{2(\alpha+\beta \operatorname{logit}(ls x))}}$$

And, as usual, the other functions of the life table can then be derived from it.

3.8.1 LIFE TABLE ESTIMATION BASED ON LINKING OF CHILD AND ADULT MORTALITY

Other functions of the life table are derived from the estimated $l^*(x)$ function obtained from linking of Child and Adult mortality. For the purpose of this dissertation, the United Nation population division's software package for mortality measurement; MORTPAK version 4.3 was used to estimate the life tables by imputing the estimated $l^*(x)$ function obtained from the linking.

3.9 ESTIMATION OF PROBABILITY OF DEATH AT CHILDHOOD USING THE HELIGMAN POLLARD MODEL

In order to appreciate important changes in child mortality and a well-defined 'hump' in the age pattern of mortality for adults, we summarize the age pattern of mortality using the eight-parameter Heligman-Pollard mortality model (Heligman and Pollard, 1980, Sharrow et al, 2013). This model decomposes the age pattern of mortality into three pieces, each with a small number of parameters to control it. There are three parameters to describe child mortality (A, B & C), three to describe a very flexible 'accident' hump typically occurring in young adulthood (D, E & F), and two parameters describe mortality at older ages (G & H). This model expresses the probability of dying as a function of age using a three-term expression that covers the entire age range (Sharrow et al, 2013).

Hence $q_x = A^{(x+B)C} + De^{-E(\ln x-\ln F)^{\wedge}2} + GH^x/1 + GH^x$

Where x indexes age, q_x is the probability of death at age x, and A; B; C; : : : ;H are eight parameters that govern the shape of the mortality curve. The eight parameters of the Heligman-Pollard model control three separate additive components corresponding to three age ranges of the mortality schedule and each parameter has a demographic interpretation (Heligman and Pollard, 1980). The parameters of the Heligman-Pollard model are described as follows: parameter A is Level of child mortality, approximately the probability of dying between ages 1 and 2, parameter B is the difference between mortality probabilities of age 0 and 1, parameter C is the decline in mortality during childhood, D is the Level (or height) of mortality hump, E is inversely related to the width of the mortality hump, F is the Location of the mortality hump on the age axis, G represents late life mortality, intercept of Gompertz curve at age 0 and H represents late life mortality, slope of Gompertz curve (Heligman and Pollard, 1980, Sharrow et al, 2013).

COMPUTATIONAL PROCEDURES

The Heligman pollard model is:

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

Where x stands for age, q_x is the probability of death at age x.

Step 1: Obtain the probabilities of death, q_1 to q_5 using brass method of child mortality estimation.

Step 2: Obtain adult mortality probabilities using siblings' method.

Step 3: Link the childhood and adult mortality estimates.

Step 4: Prepare a life table using the life table l_x, obtained from the linking

Step 2: q_1 in the life table represents parameter A of the Heligman Pollard model.

Step 3: Parameter B of the model is q_1-q_2.

Step 4: Parameter C of the model is $1 - q_{10}$

Note: the same procedure is applied for all the regions in Nigeria.

3.10 COMPARING THE RELATIONSHIP BETWEEN INFANT AND CHILDHOOD MORTALITY ESTIMATES

In order to compare the relationship between the estimates of infant and under-five mortality obtained by the Heligman pollard model and the estimates available in the Nigeria demographic and health survey reports for the respective geopolitical zones in Nigeria, graphical method was used and Statistics was used to measure the difference.

3.11 ETHICAL APPROVAL

This study is based on secondary analysis of an existing dataset, the Nigeria Demographic and Health Survey data with all participant identifiers removed. The survey instruments received ethical approval from the National Health Research Ethics Committee in the Federal Ministry of Health, Abuja, Nigeria, and from the Ethics Committee of the Opinion Research Corporation of Macro International Inc., Calverton, MD, USA. Permission to use the 2013 Nigeria Demographic and Health Survey data for this study was obtained from ICF Macro Inc.

CHAPTER FOUR

RESULTS AND INTERPRETATION OF ANALYSIS

4.0 INTRODUCTION

This section of the study presents the results obtained from analysis of data in the study and their interpretations. Results from the study include child mortality estimates for Nigeria and regions obtained using Brass method, Adult mortality estimates obtained using Siblings method, Life table estimates for Nigeria and regions obtained by linking childhood and adult mortality and Heligman Pollard model estimates of infant and under-five mortality for Nigeria and the six geopolitical zones.

4.1 UNDER-FIVE MORTALITY RATE ESTIMATE

Table 4.1 shows child mortality estimates for Nigeria. The Coale Demeny West Model Life table was used as the standard. Infant mortality ($_1q_0$) in Nigeria is 0.102, under-five mortality rate is 0.147. The probability of death obtained for Nigeria indicates high mortality at childhood ages.

Tables 4.2 to 4.7 show child mortality estimates for the six geopolitical zones in the country. There is disparity in infant mortality rate with the highest infant mortality rate of 0.126 in the North Western region and lowest infant mortality rate of 0.067 in South South region. The infant mortality rates of North Central, North East, South East and South West regions are 0.076, 0.106, 0.079 and 0.069 respectively. In all the regions, the probability of dying after infancy increased gradually with increase in age. Under-five mortality rates for the regions are 0.105, 0.156, 0.188, 0.114, 0.091 and 0.096 for North Central, North East, North West, South East, South South and South West regions respectively. Under-five mortality was highest in North West with mortality rate of 0.188 and lowest in South South with child mortality rate of 0.091. There is also disparity in under-five mortality level in the respective regions of the country.

Table 4.1: Child mortality estimates for Nigeria.

Age group	*CEB*	*DEAD*	*Total women*	*Average parity*	*Di*	*p1/p2*	*p2/p3*	*Ki*	*qx*	*Lx*
15-19	1651	203	7820	0.2111	0.1230	0.1745	0.4662	1.0265	0.1262	0.8738
20-24	8178	948	6757	1.2103	0.1159	0.1745	0.4662	1.0395	0.1205	0.8795
25-29	18550	2560	7145	2.5963	0.1380	0.1745	0.4662	1.0014	0.1382	0.8618
30-34	21638	3218	5467	3.9580	0.1487	0.1745	0.4662	1.0137	0.1508	0.8492
35-39	24787	4016	4718	5.2537	0.1620	0.1745	0.4662	1.0327	0.1673	0.8327
40-44	21365	3925	3620	5.9017	0.1837	0.1745	0.4662	1.0209	0.1876	0.8124
45-49	23106	5306	3422	6.7530	0.2296	0.1745	0.4662	1.0128	0.2326	0.7674

X	*l14*	*l15*	*level*	*ls*	*logit(lx)*	*logit(ls)*	*Alpha*	*lx(ref)*	*q(x)ref*	*tx*
1	0.8848	0.8974	14.8618	0.8957	-0.9674	-1.0749	-0.0123	0.8979	0.1021	1.1372
2	0.8575	0.8742	14.8618	0.8719	-0.9939	-0.9590	-0.0123	0.8746	0.1254	2.4156
3	0.8455	0.8639	14.8618	0.8613	-0.9152	-0.9132	-0.0123	0.8642	0.1358	4.2583
5	0.8317	0.8521	14.8618	0.8492	-0.8643	-0.8643	-0.0123	0.8524	0.1476	6.4371
10	0.8166	0.8386	14.8618	0.8355	-0.8024	-0.8127	-0.0123	0.8389	0.1611	8.8386
15	0.8054	0.8286	14.8618	0.8254	-0.7330	-0.7766	-0.0123	0.8289	0.1711	11.4525
20	0.7894	0.8141	14.8618	0.8106	-0.5969	-0.7271	-0.0123	0.8144	0.1856	14.3776

Table 4.1: Child mortality estimates for Nigeria.

Age group	*CEB*	*DEAD*	*Total women*	*Average parity*	*Di*	*p1/p2*	*p2/p3*	*Ki*	*qx*	*Lx*
15-19	1651	203	7820	0.2111	0.1230	0.1745	0.4662	1.0265	0.1262	0.8738
20-24	8178	948	6757	1.2103	0.1159	0.1745	0.4662	1.0395	0.1205	0.8795
25-29	18550	2560	7145	2.5963	0.1380	0.1745	0.4662	1.0014	0.1382	0.8618
30-34	21638	3218	5467	3.9580	0.1487	0.1745	0.4662	1.0137	0.1508	0.8492
35-39	24787	4016	4718	5.2537	0.1620	0.1745	0.4662	1.0327	0.1673	0.8327
40-44	21365	3925	3620	5.9017	0.1837	0.1745	0.4662	1.0209	0.1876	0.8124
45-49	23106	5306	3422	6.7530	0.2296	0.1745	0.4662	1.0128	0.2326	0.7674

X	*l14*	*l15*	*level*	*ls*	*logit(lx)*	*logit(ls)*	*Alpha*	*lx(ref)*	*q(x)ref*	*tx*
1	0.8848	0.8974	14.8618	0.8957	-0.9674	-1.0749	-0.0123	0.8979	0.1021	1.1372
2	0.8575	0.8742	14.8618	0.8719	-0.9939	-0.9590	-0.0123	0.8746	0.1254	2.4156
3	0.8455	0.8639	14.8618	0.8613	-0.9152	-0.9132	-0.0123	0.8642	0.1358	4.2583
5	0.8317	0.8521	14.8618	0.8492	-0.8643	-0.8643	-0.0123	0.8524	0.1476	6.4371
10	0.8166	0.8386	14.8618	0.8355	-0.8024	-0.8127	-0.0123	0.8389	0.1611	8.8386
15	0.8054	0.8286	14.8618	0.8254	-0.7330	-0.7766	-0.0123	0.8289	0.1711	11.4525
20	0.7894	0.8141	14.8618	0.8106	-0.5969	-0.7271	-0.0123	0.8144	0.1856	14.3776

Table 4.2: Child mortality estimates for North central Nigeria.

Age group	CEB	DEAD	Total women	Average parity	Di	p1/p2	p2/p3	Ki	qx	lx
15-19	182	17	1154	0.1577	0.0934	0.1421	0.4556	1.1061	0.1033	0.8967
20-24	1158	107	1043	1.1103	0.0924	0.1421	0.4556	1.0597	0.0979	0.9021
25-29	2739	264	1124	2.4368	0.0964	0.1421	0.4556	1.0038	0.0967	0.9033
30-34	2996	294	774	3.8708	0.0981	0.1421	0.4556	1.0106	0.0992	0.9008
35-39	3029	314	613	4.9413	0.1037	0.1421	0.4556	1.0274	0.1065	0.8935
40-44	2790	335	500	5.5800	0.1201	0.1421	0.4556	1.0150	0.1219	0.8781
45-49	2251	326	366	6.1503	0.1448	0.1421	0.4556	1.0071	0.1459	0.8541

X	l17	l18	level	ls	logit(lx)	logit(ls)	Alpha	lx(ref)	q(x)ref	tx
1	0.9214	0.9327	17.6135	0.9283	-1.0804	-1.2804	0.0360	0.9233	0.0767	0.9780
2	0.9058	0.9206	17.6135	0.9149	-1.1103	-1.1874	0.0360	0.9091	0.0909	2.2320
3	0.8986	0.9148	17.6135	0.9085	-1.1169	-1.1480	0.0360	0.9024	0.0976	4.1239
5	0.8900	0.9077	17.6135	0.9008	-1.1032	-1.1032	0.0360	0.8942	0.1058	6.4057
10	0.8799	0.8992	17.6135	0.8917	-1.0635	-1.0541	0.0360	0.8845	0.1155	8.9403
15	0.8722	0.8927	17.6135	0.8848	-0.9874	-1.0193	0.0360	0.8772	0.1228	11.6685
20	0.8608	0.8828	17.6135	0.8743	-0.8837	-0.9696	0.0360	0.8661	0.1339	14.6266

Table 4.3: Child mortality estimates for North east, Nigeria.

Age group	*CEB*	*DEAD*	*Total women*	*Average parity*	*Di*	*p1/p2*	*p2/p3*	*Ki*	*qx*	*lx*
15-19	398	59	1190	0.3346	0.1482	0.2018	0.5265	0.9988	0.1481	0.8519
20-24	1771	211	1068	1.6580	0.1191	0.2018	0.5265	1.0089	0.1202	0.8798
25-29	3339	504	1060	3.1489	0.1509	0.2018	0.5265	0.9779	0.1476	0.8524
30-34	3666	615	787	4.6607	0.1678	0.2018	0.5265	0.9943	0.1668	0.8332
35-39	4168	816	679	6.1345	0.1958	0.2018	0.5265	1.0142	0.1986	0.8014
40-44	3497	757	500	6.9959	0.2165	0.2018	0.5265	1.0026	0.2170	0.7830
45-49	3441	917	482	7.1386	0.2665	0.2018	0.5265	0.9947	0.2651	0.7349

X	*l14*	*l15*	*level*	*ls*	*logit(lx)*	*logit(ls)*	*Alpha*	*lx(ref)*	*q(x)ref*	*tx*
1	0.8848	0.8974	14.0718	0.8857	-0.8750	-1.0236	-0.0383	0.8932	0.1068	1.1687
2	0.8575	0.8742	14.0718	0.8587	-0.9953	-0.9024	-0.0383	0.8678	0.1322	2.5856
3	0.8455	0.8639	14.0718	0.8468	-0.8767	-0.8548	-0.0383	0.8565	0.1435	4.6236
5	0.8317	0.8521	14.0718	0.8332	-0.8042	-0.8042	-0.0383	0.8436	0.1564	7.0004
10	0.8166	0.8386	14.0718	0.8182	-0.6976	-0.7520	-0.0383	0.8293	0.1707	9.5856
15	0.8054	0.8286	14.0718	0.8071	-0.6415	-0.7155	-0.0383	0.8187	0.1813	12.3100
20	0.7894	0.8141	14.0718	0.7912	-0.5098	-0.6659	-0.0383	0.8035	0.1965	15.1979

Table 4.4: Child mortality estimates for North west, Nigeria.

Age group	CEB	DEAD	Total women	Average parity	Di	p1/p2	p2/p3	Ki	qx	lx
15-19	792	101	2428	0.3262	0.1275	0.1950	0.4786	0.9805	0.1250	0.8750
20-24	3416	480	2042	1.6728	0.1405	0.1950	0.4786	1.0252	0.1441	0.8559
25-29	7517	1336	2151	3.4949	0.1777	0.1950	0.4786	0.9975	0.1773	0.8227
30-34	8104	1603	1623	4.9938	0.1978	0.1950	0.4786	1.0132	0.2004	0.7996
35-39	9324	2050	1399	6.6634	0.2199	0.1950	0.4786	1.0335	0.2272	0.7728
40-44	7429	1912	1069	6.9463	0.2574	0.1950	0.4786	1.0221	0.2630	0.7370
45-49	9565	2910	1164	8.2199	0.3042	0.1950	0.4786	1.0138	0.3084	0.6916

X	l12	l13	level	ls	logit(lx)	logit(ls)	Alpha	lx(ref)	q(x)ref	tx
1	0.8562	0.8709	12.6123	0.8652	-0.9728	-0.9295	-0.0379	0.8738	0.1262	1.2265
2	0.8196	0.8390	12.6123	0.8315	-0.8910	-0.7981	-0.0379	0.8418	0.1582	2.5335
3	0.8035	0.8249	12.6123	0.8166	-0.7674	-0.7467	-0.0379	0.8277	0.1723	4.3717
5	0.7850	0.8088	12.6123	0.7996	-0.6919	-0.6919	-0.0379	0.8115	0.1885	6.5174
10	0.7663	0.7919	12.6123	0.7820	-0.6120	-0.6385	-0.0379	0.7946	0.2054	8.8678
15	0.7526	0.7794	12.6123	0.7690	-0.5151	-0.6013	-0.0379	0.7822	0.2178	11.4325
20	0.7339	0.7620	12.6123	0.7511	-0.4037	-0.5523	-0.0379	0.7650	0.2350	14.3357

Table 4.5: Child mortality estimates for South east, Nigeria.

Age group	*CEB*	*DEAD*	*Total women*	*Average parity*	*Di*	*p1/p2*	*p2/p3*	*Ki*	*qx*	*lx*
15-19	65	6	894	0.0727	0.0923	0.1203	0.3578	1.0900	0.1006	0.8994
20-24	484	42	801	0.6044	0.0868	0.1203	0.3578	1.0972	0.0952	0.9048
25-29	1341	119	794	1.6894	0.0887	0.1203	0.3578	1.0433	0.0926	0.9074
30-34	1739	220	560	3.1040	0.1265	0.1203	0.3578	1.0473	0.1325	0.8675
35-39	2137	261	513	4.1635	0.1221	0.1203	0.3578	1.0643	0.1300	0.8700
40-44	2401	335	470	5.1119	0.1395	0.1203	0.3578	1.0521	0.1468	0.8532
45-49	2786	530	445	6.2653	0.1902	0.1203	0.3578	1.0436	0.1985	0.8015

X	*l15*	*l16*	*level*	*ls*	*logit(lx)*	*logit(ls)*	*Alpha*	*lx(ref)*	*q(x)ref*	*tx*
1	0.8974	0.9096	15.7966	0.9071	-1.0952	-1.1396	-0.0834	0.9203	0.0797	1.0522
2	0.8742	0.8903	15.7966	0.8870	-1.1258	-1.0303	-0.0834	0.9027	0.0973	2.0819
3	0.8639	0.8816	15.7966	0.8780	-1.1413	-0.9867	-0.0834	0.8947	0.1053	3.5893
5	0.8521	0.8715	15.7966	0.8675	-0.9395	-0.9395	-0.0834	0.8855	0.1145	5.4382
10	0.8386	0.8597	15.7966	0.8554	-0.9506	-0.8887	-0.0834	0.8748	0.1252	7.5403
15	0.8286	0.8509	15.7966	0.8463	-0.8800	-0.8530	-0.0834	0.8668	0.1332	9.9804
20	0.8141	0.8379	15.7966	0.8330	-0.6977	-0.8036	-0.0834	0.8549	0.1451	12.9772

Table 4.6: Child mortality estimates for South south, Nigeria.

Age group	CEB	DEAD	Total women	Average parity	Di	p1/p2	p2/p3	Ki	qx	lx
15-19	130	9	1033	0.1259	0.0692	0.1648	0.4748	1.0594	0.0733	0.9267
20-24	663	57	868	0.7639	0.0860	0.1648	0.4748	1.0424	0.0896	0.9104
25-29	1448	114	900	1.6088	0.0787	0.1648	0.4748	0.9972	0.0785	0.9215
30-34	2040	178	681	2.9943	0.0873	0.1648	0.4748	1.0077	0.0879	0.9121
35-39	2586	284	613	4.2164	0.1098	0.1648	0.4748	1.0259	0.1127	0.8873
40-44	2290	239	435	5.2603	0.1044	0.1648	0.4748	1.0138	0.1058	0.8942
45-49	2283	268	411	5.5498	0.1174	0.1648	0.4748	1.0059	0.1181	0.8819

X	l18	l19	level	ls	logit(lx)	logit(ls)	Alpha	lx(ref)	q(x)ref	tx
1	0.9327	0.9434	18.2613	0.9355	-1.2682	-1.3369	0.0244	0.9325	0.0675	1.0659
2	0.9206	0.9345	18.2613	0.9242	-1.1591	-1.2506	0.0244	0.9207	0.0793	2.3641
3	0.9148	0.9301	18.2613	0.9188	-1.2314	-1.2130	0.0244	0.9151	0.0849	4.2759
5	0.9077	0.9245	18.2613	0.9121	-1.1696	-1.1696	0.0244	0.9081	0.0919	6.5509
10	0.8992	0.9176	18.2613	0.9040	-1.0319	-1.1212	0.0244	0.8997	0.1003	9.0601
15	0.8927	0.9123	18.2613	0.8978	-1.0672	-1.0867	0.0244	0.8933	0.1067	11.7557
20	0.8828	0.9040	18.2613	0.8883	-1.0054	-1.0368	0.0244	0.8834	0.1166	14.6885

Table 4.7: Child mortality estimates for South west Nigeria.

Age group	*CEB*	*DEAD*	*Total women*	*Average parity*	*Di*	*p1/p2*	*p2/p3*	*Ki*	*qx*	*lx*
15-19	82	9	1121	0.0732	0.1098	0.1010	0.3742	1.1549	0.1268	0.8732
20-24	678	46	936	0.7248	0.0679	0.1010	0.3742	1.1033	0.0749	0.9251
25-29	2162	197	1116	1.9369	0.0911	0.1010	0.3742	1.0352	0.0943	0.9057
30-34	3080	295	1042	2.9545	0.0958	0.1010	0.3742	1.0358	0.0992	0.9008
35-39	3532	330	900	3.9261	0.0934	0.1010	0.3742	1.0510	0.0982	0.9018
40-44	2962	360	646	4.5870	0.1215	0.1010	0.3742	1.0383	0.1262	0.8738
45-49	2807	378	554	5.0632	0.1347	0.1010	0.3742	1.0302	0.1387	0.8613

X	*l17*	*l18*	*level*	*ls*	*logit(lx)*	*logit(ls)*	*Alpha*	*lx(ref)*	*q(x)ref*	*tx*
1	0.9214	0.9327	17.6116	0.9283	-0.9650	-1.2802	-0.0177	0.9306	0.0694	0.9120
2	0.9058	0.9206	17.6116	0.9149	-1.2572	-1.1872	-0.0177	0.9176	0.0824	1.9792
3	0.8986	0.9148	17.6116	0.9085	-1.1310	-1.1478	-0.0177	0.9114	0.0886	3.6203
5	0.8900	0.9077	17.6116	0.9008	-1.1030	-1.1030	-0.0177	0.9039	0.0961	5.6561
10	0.8799	0.8992	17.6116	0.8917	-1.1087	-1.0539	-0.0177	0.8950	0.1050	7.9680
15	0.8722	0.8927	17.6116	0.8847	-0.9675	-1.0191	-0.0177	0.8883	0.1117	10.5674
20	0.8608	0.8828	17.6116	0.8742	-0.9130	-0.9694	-0.0177	0.8781	0.1219	13.5797

Figure 1 shows the comparison of infant mortality rates among the six geopolitical zones, infant mortality rate varied among the zone with North West having the highest infant mortality rate of 0.126. South South had the lowest infant mortality rate of 0.067. Infant mortality rate in North central is 0.076, 0.106 in the North east, 0.079 in South East region and 0.069 in the South West.

Figure 1: Comparison of infant mortality estimates in the six geopolitical zones.

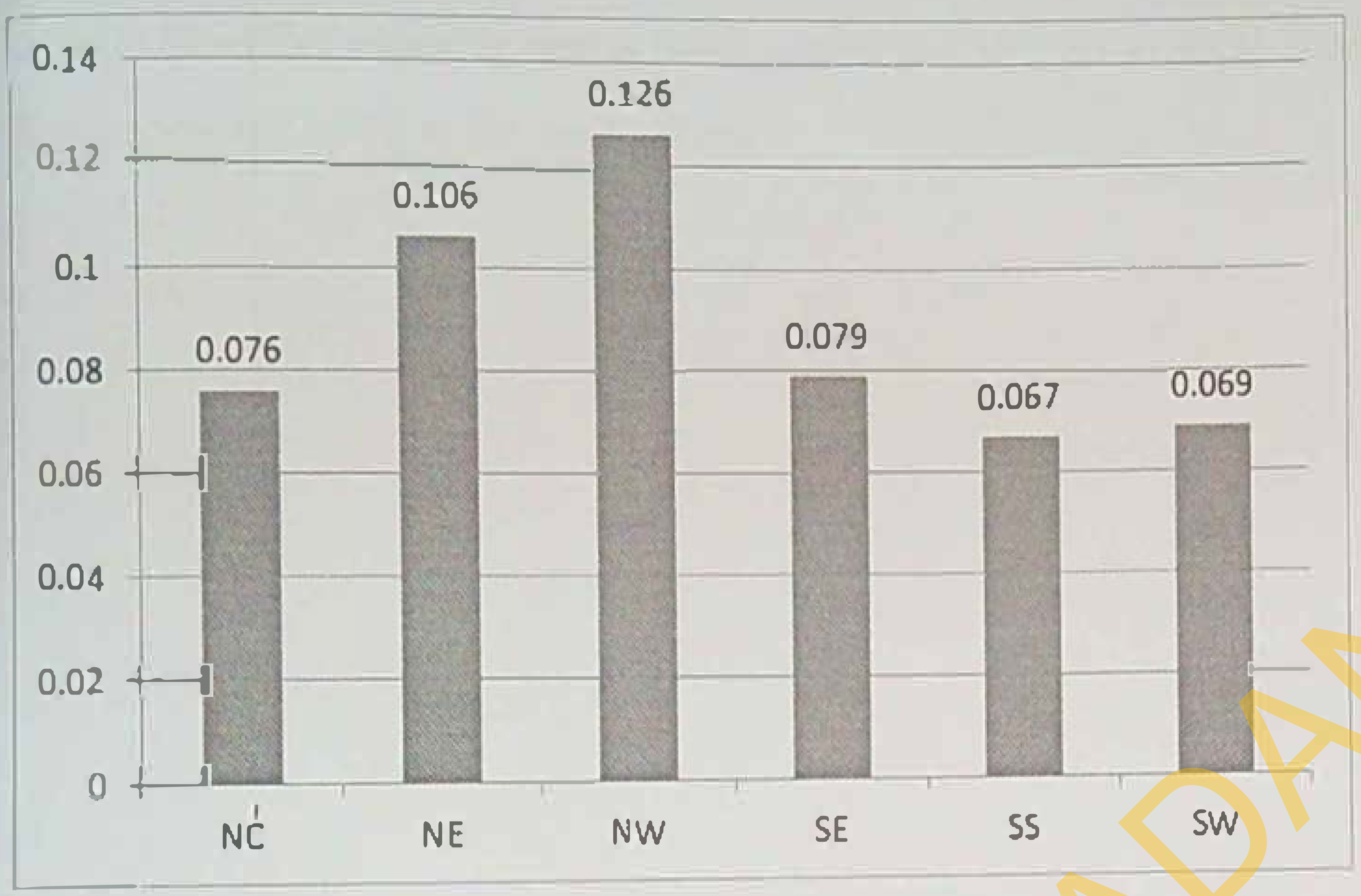
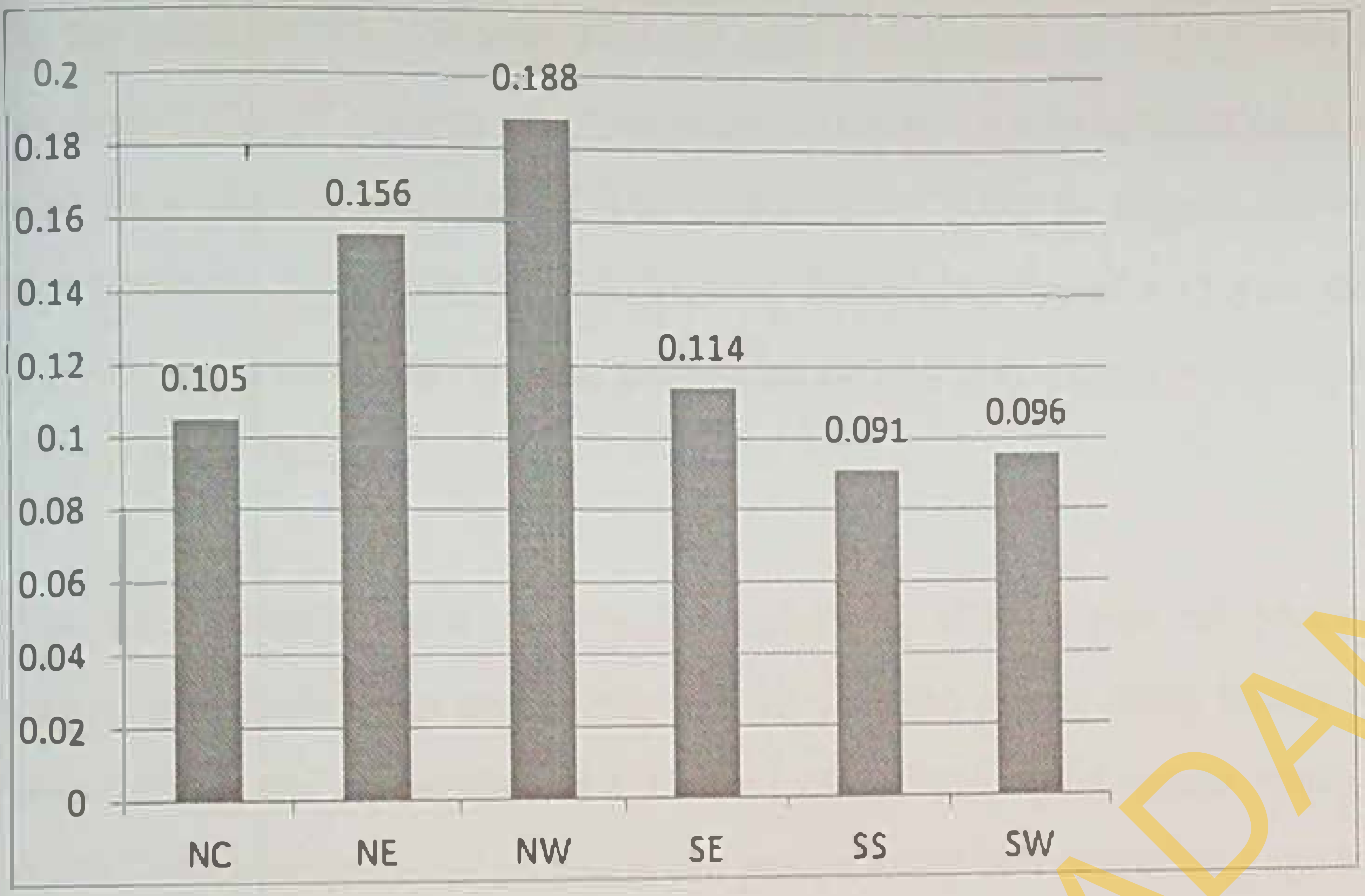


Figure 2 shows the comparison of under-five mortality estimates obtained for the six geopolitical zones in Nigeria, under-five mortality rate varied among the zones with North West having the highest under-five mortality rate of 0.188. South South had the lowest infant mortality rate of 0.091. Under-five mortality rate in North central is 0.105, 0.156 in the North east, 0.144 in South East region and 0.096 in the South West.

Figure 2: Comparison of under-five mortality estimates in the six geopolitical zones.



4.2 ADULT MORTALITY RATE ESTIMATE

Table 4.8 shows the adult mortality estimates for Nigeria derived from information on Siblings provided by respondents aged 15-49 years. The Coale Demeny West Model Life table was used as the standard. The column 4 of the table (proportion of siblings still alive) reduced as age increased. The 8th column which estimates the survivorship between exact age 15years and 15+n, also showed a downward trend. The probability of dying for Nigeria showed a trend reduction as age increases from 25 to 50. For Nigeria, The probability of a 15 year old person dying before age 40 ($_{25}q_{15}$) was 0.084 and the probability of a 15 year old person dying before reaching age 45 ($_{30}q_{15}$) was 0.0693.

The adult mortality index that is the probability of a 15 year old person dying before age 50 ($_{35}q_{15}$) was 0.0611, the probability of a 15 year old person dying before reaching age 55 ($_{40}q_{15}$) was 0.0593, the probability of a 15 year old person dying before reaching age 60 ($_{45}q_{15}$) was 0.0517 and probability of a 15 year old person dying before reaching age 65 ($_{50}q_{15}$) was 0.0528.

Table 4.8: Adult mortality estimates for Nigeria

Age group	*Siblings alive at 15*	*Siblings Dead*	*Proportion still alive*	*N*	*a(n)*	*b(n)*	$l_{(n)}/l_{(15)}$
15-19	20226	438	0.9788				
20-24	24566	685	0.9729	25	-0.0003	1.0011	0.9736
25-29	30640	1004	0.9683	30	-0.1546	1.156	0.9647
30-34	24589	1018	0.9603	35	-0.1645	1.166	0.9551
35-39	21688	1228	0.9464	40	-0.1388	1.1406	0.9407
40-44	16265	1111	0.9361	45	-0.114	1.1168	0.9314
45-49	14202	1358	0.9127	50	-0.1018	1.1066	0.9082

l14	*l15*	*ls(n)*	*ls(15)*	*level (a)*	*logit(ls)*	λs(15)	*ls(15+x)*	λs(15+x)	q_{ls}
0.8054	0.8286								
0.7680	0.7946	0.7909	0.8253	-0.2760	-0.6652	-0.7764	0.7191	-0.4699	0.0842
0.7450	0.7735	0.7695	0.8253	-0.3922	-0.6028	-0.7764	0.7191	-0.4699	0.0693
0.7195	0.7502	0.7459	0.8253	-0.4656	-0.5383	-0.7764	0.7191	-0.4699	0.0611
0.6910	0.7237	0.7191	0.8253	-0.4830	-0.4699	-0.7764	0.7191	-0.4699	0.0593
0.6584	0.6928	0.6880	0.8253	-0.5613	-0.3953	-0.7764	0.7191	-0.4699	0.0517
0.6204	0.6560	0.6510	0.8253	-0.5492	-0.3117	-0.7764	0.7191	-0.4699	0.0528

Tables 4.9 to 4.11 show the adult mortality estimates derived from information on Siblings provided by respondents aged 15-49 for North Central, North East and North West Nigeria (the Northern geopolitical zones). The probability of a 15 year old person dying before age 40 (${}_{25}q_{15}$) among the Northern zones are 0.081, 0.120 and 0.068 for North Central, North East, North West zones respectively, it is highest in North East (0.120) and lowest in North West (0.068). The probability of a 15 year old person dying before reaching age 45 (${}_{30}q_{15}$) was 0.053, 0.099 and 0.059 for the respective zones.

The adult mortality index that is the probability of a 15 year old person dying before age 50 (${}_{35}q_{15}$) was 0.0605, 0.085 and 0.0507 in North Central, North East, North West zones respectively. The probability of a 15 year old person dying before reaching age 55 (${}_{40}q_{15}$) was 0.055, 0.075 and 0.048 in North Central, North East, North West zones respectively, the probability of a 15 year old person dying before reaching age 60 (${}_{45}q_{15}$) was 0.053, 0.073 and 0.039 for North Central, North East, North West zones respectively. The probability of dying is highest in the North East (0.073) and lowest in North West (0.039). Probability of a 15 year old person dying before reaching age 65 (${}_{50}q_{15}$) are 0.050, 0.066, 0.048, for North Central, North East, North West, regions respectively. In all the Northern regions of the country, the proportion of siblings still alive decreased as age increased.

Tables 4.9 to 4.11 show the adult mortality estimates derived from information on Siblings provided by respondents aged 15-49 for North Central, North East and North West Nigeria (the Northern geopolitical zones). The probability of a 15 year old person dying before age 40 (${}_{25}q_{15}$) among the Northern zones are 0.081, 0.120 and 0.068 for North Central, North East, North West zones respectively, it is highest in North East (0.120) and lowest in North West (0.068). The probability of a 15 year old person dying before reaching age 45 (${}_{30}q_{15}$) was 0.053, 0.099 and 0.059 for the respective zones.

The adult mortality index that is the probability of a 15 year old person dying before age 50 (${}_{35}q_{15}$) was 0.0605, 0.085 and 0.0507 in North Central, North East, North West zones respectively. The probability of a 15 year old person dying before reaching age 55 (${}_{40}q_{15}$) was 0.055, 0.075 and 0.048 in North Central, North East, North West zones respectively, the probability of a 15 year old person dying before reaching age 60 (${}_{45}q_{15}$) was 0.053, 0.073 and 0.039 for North Central, North East, North West zones respectively. The probability of dying is highest in the North East (0.073) and lowest in North West (0.039). Probability of a 15 year old person dying before reaching age 65 (${}_{50}q_{15}$) are 0.050, 0.066, 0.048, for North Central, North East, North West, regions respectively. In all the Northern regions of the country, the proportion of siblings still alive decreased as age increased.

Table 4.9: Adult mortality estimates for North central, Nigeria

Age group	*Siblings alive at 15*	*Siblings Dead*	*Proportion still alive*	*n*	*a(n)*	*b(n)*	$l_{(n)}/l_{(15)}$
15-19	3131	68	0.9787				
20-24	4059	110	0.9736	25	-0.0003	1.0011	0.9744
25-29	5010	126	0.9755	30	-0.1546	1.156	0.9730
30-34	3671	150	0.9607	35	-0.1645	1.166	0.9557
35-39	2951	157	0.9495	40	-0.1388	1.1406	0.9442
40-44	2349	168	0.9333	45	-0.114	1.1168	0.9283
45-49	1685	157	0.9148	50	-0.1018	1.1066	0.9105

l17	*l18*	*ls(n)*	*ls(15)*	*level (α)*	*logit(ls)*	λs(15)	*ls(15+x)*	λs(15+x)	$_{x}q_{15}$
0.8722	0.8927								
0.8453	0.8693	0.8659	0.8898	-0.0279	-0.9326	-1.0445	0.8140	-0.7383	0.0814
0.8284	0.8546	0.8509	0.8898	-0.2749	-0.8708	-1.0445	0.8140	-0.7383	0.0533
0.8094	0.8380	0.8340	0.8898	-0.2031	-0.8070	-1.0445	0.8140	-0.7383	0.0605
0.7874	0.8184	0.8140	0.8898	-0.2492	-0.7383	-1.0445	0.8140	-0.7383	0.0558
0.7607	0.7941	0.7894	0.8898	-0.2727	-0.6608	-1.0445	0.8140	-0.7383	0.0536
0.7272	0.7627	0.7577	0.8898	-0.3129	-0.5700	-1.0445	0.8140	-0.7383	0.0499

Table 4.9: Adult mortality estimates for North central, Nigeria

Age group	*Siblings alive at 15*	*Siblings Dead*	*Proportion still alive*	*n*	*a(n)*	*b(n)*	$l_{(n)}/l_{(15)}$
15-19	3131	68	0.9787				
20-24	4059	110	0.9736	25	-0.0003	1.0011	0.9744
25-29	5010	126	0.9755	30	-0.1546	1.156	0.9730
30-34	3671	150	0.9607	35	-0.1645	1.166	0.9557
35-39	2951	157	0.9495	40	-0.1388	1.1406	0.9442
40-44	2349	168	0.9333	45	-0.114	1.1168	0.9283
45-49	1685	157	0.9148	50	-0.1018	1.1066	0.9105

l17	*l18*	*ls(n)*	*ls(15)*	*level (a)*	*logit(ls)*	λs(15)	*ls(15+x)*	λs(15+x)	$_{x}q_{15}$
0.8722	0.8927								
0.8453	0.8693	0.8659	0.8898	-0.0279	-0.9326	-1.0445	0.8140	-0.7383	0.0814
0.8284	0.8546	0.8509	0.8898	-0.2749	-0.8708	-1.0445	0.8140	-0.7383	0.0533
0.8094	0.8380	0.8340	0.8898	-0.2031	-0.8070	-1.0445	0.8140	-0.7383	0.0605
0.7874	0.8184	0.8140	0.8898	-0.2492	-0.7383	-1.0445	0.8140	-0.7383	0.0558
0.7607	0.7941	0.7894	0.8898	-0.2727	-0.6608	-1.0445	0.8140	-0.7383	0.0536
0.7272	0.7627	0.7577	0.8898	-0.3129	-0.5700	-1.0445	0.8140	-0.7383	0.0499

Table 4.10: Adult mortality estimates for North east, Nigeria

Age group	*Siblings alive at 15*	*Siblings Dead*	*Proportion still alive*	*n*	*a(n)*	*b(n)*	$l_{(n)}/l_{(15)}$
15-19	3098	107	0.9666				
20-24	3905	160	0.9606	25	-0.0003	1.0011	0.9613
25-29	4719	226	0.9543	30	-0.1546	1.156	0.9485
30-34	3591	211	0.9445	35	-0.1645	1.166	0.9367
35-39	3218	233	0.9325	40	-0.1388	1.1406	0.9247
40-44	2303	224	0.9114	45	-0.114	1.1168	0.9038
45-49	1987	239	0.8926	50	-0.1018	1.1066	0.8859

l14	*l15*	*ls(n)*	*ls(15)*	*level (α)*	*logit(ls)*	λs(15)	*ls(15+x)*	λs(15+x)	$_xq_{15}$
0.8054	0.8286								
0.7680	0.7946	0.7909	0.8253	-0.0485	-0.6652	-0.7764	0.7191	-0.4699	0.1199
0.7450	0.7735	0.7695	0.8253	-0.1713	-0.6028	-0.7764	0.7191	-0.4699	0.0995
0.7195	0.7502	0.7459	0.8253	-0.2658	-0.5383	-0.7764	0.7191	-0.4699	0.0856
0.6910	0.7237	0.7191	0.8253	-0.3440	-0.4700	-0.7764	0.7191	-0.4699	0.0752
0.6584	0.6928	0.6880	0.8253	-0.3617	-0.3953	-0.7764	0.7191	-0.4699	0.0730
0.6204	0.6560	0.6510	0.8253	-0.4186	-0.3117	-0.7764	0.7191	-0.4699	0.0663

Table 4.11: Adult mortality estimates for North west, Nigeria

Age group	Siblings alive at 15	Siblings Dead	Proportion still alive	n	a(n)	b(n)	$l_{(n)}/l_{(15)}$
15-19	6205	117	0.9815				
20-24	7064	158	0.9781	25	-0.0003	1.0011	0.9789
25-29	8490	236	0.9730	30	-0.1546	1.156	0.9701
30-34	6741	230	0.9670	35	-0.1645	1.166	0.9630
35-39	5972	276	0.9558	40	-0.1388	1.1406	0.9514
40-44	4469	235	0.9500	45	-0.114	1.1168	0.9470
45-49	4597	402	0.9196	50	-0.1018	1.1066	0.9158

l12	l13	ls(n)	ls(15)	level (α)	logit(ls)	λs(15)	ls(15+x)	λs(15+x)	$_xq_{15}$
0.7526	0.7794								
0.7094	0.7392	0.7350	0.7756	-0.5522	-0.5101	-0.6202	0.6521	-0.3142	0.0688
0.6830	0.7145	0.7101	0.7756	-0.6374	-0.4479	-0.6202	0.6521	-0.3142	0.0594
0.6540	0.6873	0.6826	0.7756	-0.7278	-0.3829	-0.6202	0.6521	-0.3142	0.0507
0.6221	0.6570	0.6521	0.7756	-0.7512	-0.3142	-0.6202	0.6521	-0.3142	0.0486
0.5864	0.6228	0.6177	0.7756	-0.8614	-0.2400	-0.6202	0.6521	-0.3142	0.0398
0.5465	0.5839	0.5787	0.7756	-0.7503	-0.1587	-0.6202	0.6521	-0.3142	0.0487

Tables 4.12 to 4.14 show the adult mortality estimates derived from information on Siblings provided by respondents aged 15-49 for South East, South South and South West regions respectively (Southern geopolitical zones). The probability of a 15 year old person dying before age 40 (${}_{25}q_{15}$) among the Southern zones are 0.090, 0.083 and 0.069 for South East, South South and South West regions respectively, it is highest in South East (0.090) and lowest in South West zone (0.069). The probability of a 15 year old person dying before reaching age 45 (${}_{30}q_{15}$) in the 3 zones are 0.078, 0.076 and 0.0568.

The adult mortality index that is the probability of a 15 year old person dying before age 50 (${}_{35}q_{15}$) are 0.069, 0.055 and 0.057 in South East, South South and South West regions respectively. The probability of a 15 year old person dying before reaching age 55 (${}_{40}q_{15}$) was 0.060, 0.074 and 0.0513 in South East, South South and South West regions respectively, the probability of a 15 year old person dying before reaching age 60 (${}_{45}q_{15}$) was 0.055, 0.056 and 0.0471 for the respective zones and the probability of a 15 year old person dying before reaching age 65 (${}_{50}q_{15}$) are 0.068, 0.051 and 0.0433 for South East, South South and South West regions respectively. In all the Southern regions of the country, the proportion of siblings still alive decreased as age increased.

Table 4.12: Adult mortality estimates for South east, Nigeria

Age group	Siblings alive at 15	Siblings Dead	Proportion still alive	n	a(n)	b(n)	$l_{(n)}/l_{(15)}$
15-19	2592	58	0.9781				
20-24	3194	97	0.9705	25	-0.0003	1.0011	0.9713
25-29	3807	141	0.9643	30	-0.1546	1.156	0.9601
30-34	2715	128	0.9550	35	-0.1645	1.166	0.9490
35-39	2533	145	0.9459	40	-0.1388	1.1406	0.9400
40-44	2149	157	0.9319	45	-0.114	1.1168	0.9268
45-49	1762	221	0.8886	50	-0.1018	1.1066	0.8815

l15	l16	ls(n)	ls(15)	level (α)	logit(ls)	λs(15)	ls(15+x)	λs(15+x)	$_{x}q_{15}$
0.8286	0.8509								
0.7946	0.8204	0.8168	0.8477	-0.1441	-0.7473	-0.8585	0.7513	-0.5528	0.0909
0.7735	0.8014	0.7975	0.8477	-0.2383	-0.6852	-0.8585	0.7513	-0.5528	0.0780
0.7502	0.7802	0.7760	0.8477	-0.3078	-0.6211	-0.8585	0.7513	-0.5528	0.0694
0.7237	0.7558	0.7513	0.8477	-0.3928	-0.5528	-0.8585	0.7513	-0.5528	0.0600
0.6928	0.7269	0.7221	0.8477	-0.4411	-0.4776	-0.8585	0.7513	-0.5528	0.0551
0.6560	0.6916	0.6866	0.8477	-0.3152	-0.3922	-0.8585	0.7513	-0.5528	0.0685

Table 4.13: Adult mortality estimates for South South, Nigeria

Age group	*Siblings alive at 15*	*Siblings Dead*	*Proportion still alive*	*n*	*a(n)*	*b(n)*	$l_{(n)}/l_{(15)}$
15-19	2746	51	0.9818				
20-24	3195	89	0.9729	25	-0.0003	1.0011	0.9737
25-29	3845	139	0.9651	30	-0.1546	1.156	0.9611
30-34	3188	118	0.9643	35	-0.1645	1.166	0.9599
35-39	2855	205	0.9330	40	-0.1388	1.1406	0.9254
40-44	2061	155	0.9301	45	-0.114	1.1168	0.9247
45-49	1824	177	0.9115	50	-0.1018	1.1066	0.9069

l18	*l19*	*ls(n)*	*ls(15)*	*level (a)*	*logit(ls)*	λs(15)	*ls(15+x)*	λs(15+x)	$_{1}q_{15}$
0.8927	0.9123								
0.8693	0.8924	0.8892	0.9096	0.0911	-1.0412	-1.1543	0.8444	-0.8457	0.0834
0.8546	0.8799	0.8763	0.9096	0.0361	-0.9791	-1.1543	0.8444	-0.8457	0.0762
0.8380	0.8657	0.8618	0.9096	-0.1534	-0.9152	-1.1543	0.8444	-0.8457	0.0550
0.8184	0.8486	0.8444	0.9096	0.0239	-0.8457	-1.1543	0.8444	-0.8457	0.0746
0.7941	0.8269	0.8223	0.9096	-0.1436	-0.7661	-1.1543	0.8444	-0.8457	0.0559
0.7627	0.7978	0.7929	0.9096	-0.1952	-0.6711	-1.1543	0.8444	-0.8457	0.0511

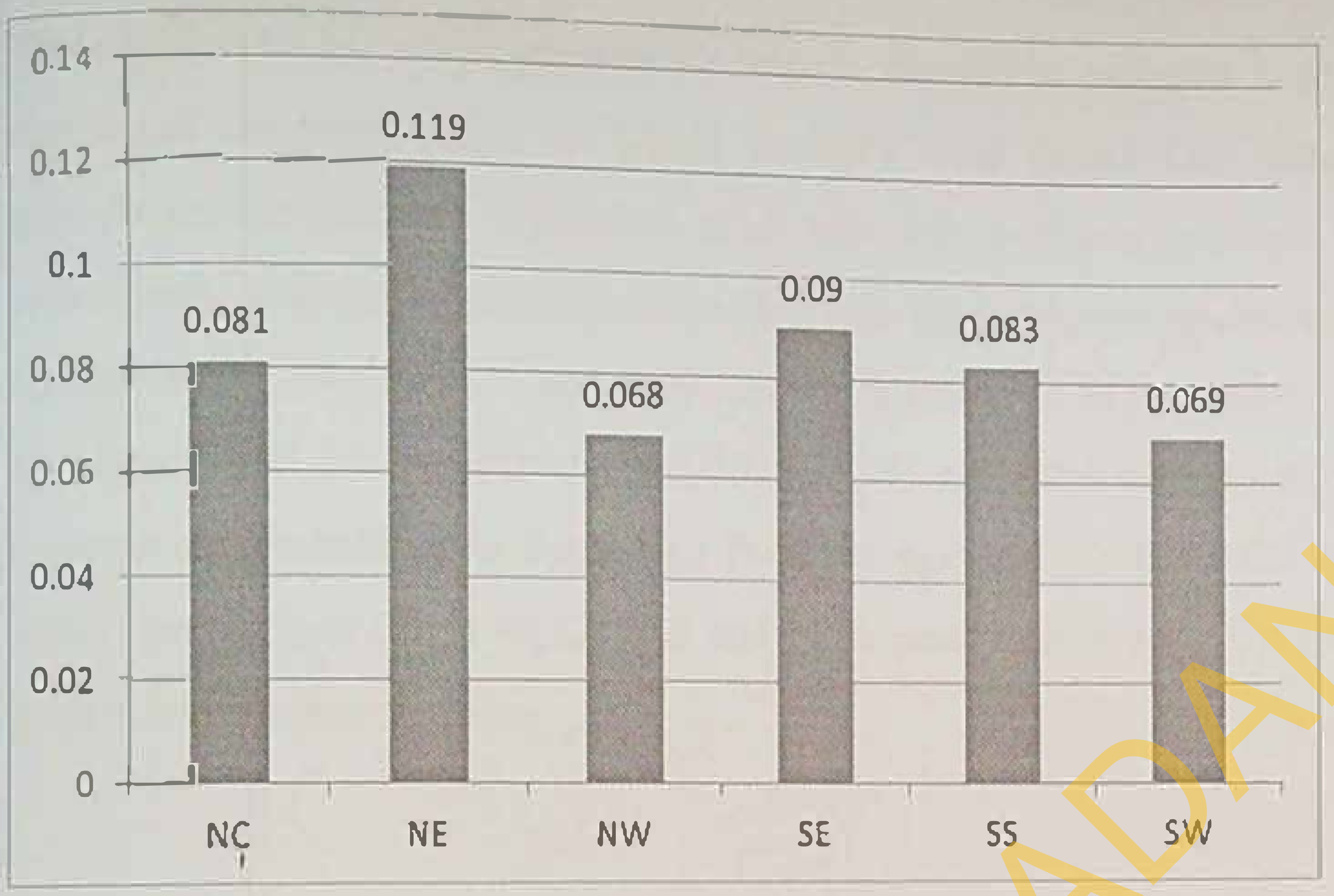
Table 4.14: Adult mortality estimates for South west, Nigeria

Age group	*Siblings alive at 15*	*Siblings Dead*	*Proportion still alive*	*n*	*a(n)*	*b(n)*	$l_{(n)}/l_{(15)}$
15-19	2469	43	0.9829				
20-24	3156	72	0.9777	25	-0.0003	1.0011	0.9785
25-29	4738	127	0.9739	30	-0.1546	1.156	0.9712
30-34	4685	180	0.9630	35	-0.1645	1.166	0.9584
35-39	4160	203	0.9535	40	-0.1388	1.1406	0.9487
40-44	2948	185	0.9410	45	-0.114	1.1168	0.9369
45-49	2417	195	0.9253	50	-0.1018	1.1066	0.9222

l17	*l18*	*ls(n)*	*ls(15)*	*level (α)*	*logit(ls)*	λs(15)	*ls(15+x)*	λs(15+x)	$_{x}q_{15}$
0.8722	0.8927								
0.8453	0.8693	0.8659	0.8898	-0.1263	-0.9326	-1.0445	0.8140	-0.7383	0.0690
0.8284	0.8546	0.8509	0.8898	-0.2389	-0.8708	-1.0445	0.8140	-0.7383	0.0568
0.8094	0.8380	0.8340	0.8898	-0.2377	-0.8070	-1.0445	0.8140	-0.7383	0.0570
0.7874	0.8184	0.8140	0.8898	-0.2973	-0.7383	-1.0445	0.8140	-0.7383	0.0513
0.7607	0.7941	0.7894	0.8898	-0.3457	-0.6608	-1.0445	0.8140	-0.7383	0.0470
0.7272	0.7627	0.7577	0.8898	-0.3940	-0.5700	-1.0445	0.8140	-0.7383	0.0431

Figure 3 shows comparison of Adult mortality estimates obtained for the six geopolitical zones, probability of dying was highest in North east (0.119), followed by the South East region(0.090). Adult mortality rate was lowest in North West region with a mortality rate of 0.068. The Adult mortality estimates obtained for North Central was 0.081, 0.083 in South South and 0.069 in South west.

Figure 3: Comparison of Adult mortality estimates across the six geopolitical zones



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4.3 LIFE TABLE ESTIMATION BASED ON LINKING OF CHILD AND ADULT MORTALITY

Table 4.15 show life table estimates for Nigeria, derived by estimates from linking of Childhood and Adult mortality using the Coale Demeny West Model Life table as the standard. It summarizes the mortality experience at all ages with particular reference to age 20, 50 and 65 respectively. The survivorship functions (l_x) show the number of persons alive at above reference ages are 83112.57, 70852.11 and 56099.29 which means 83.112%, 70.852% and 56.099% live to age 20, 50 and 65 respectively and 1525, 3679 and 8230 died prior to age 25, 55 and 70 respectively, probability of dying (q_x) for those ages are 0.018, 0.0519 and 0.146 respectively with expectation of life at 49.22, 24.8 and 14.09 years respectively. The expectation of life from birth in Nigeria was 58 years.

Table 4.15: Life table estimates for Nigeria

Age	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.114	0.106	100000.000	10576.326	93125.386	0.884	5802840.313	58.028
1	0.009	0.037	89423.674	3286.454	349021.736	0.968	5709714.928	63.850
5	0.003	0.013	86137.221	1080.995	427983.616	0.989	5360693.192	62.234
10	0.002	0.009	85056.225	797.035	423288.539	0.989	4932709.576	57.994
15	0.003	0.014	84259.190	1146.620	418584.392	0.984	4509421.038	53.518
20	0.004	0.018	83112.570	1525.017	411864.490	0.981	4090836.645	49.220
25	0.004	0.020	81587.553	1644.584	403886.030	0.979	3678972.155	45.092
30	0.005	0.023	79942.970	1814.643	395261.570	0.976	3275086.125	40.968
35	0.005	0.026	78128.327	2049.446	385634.754	0.971	2879824.555	36.860
40	0.006	0.031	76078.882	2383.893	374597.521	0.965	2494189.801	32.784
45	0.008	0.039	73694.989	2842.880	361626.228	0.955	2119592.280	28.762
50	0.011	0.052	70852.109	3679.504	345450.290	0.940	1757966.052	24.812
55	0.015	0.070	67172.605	4712.432	324624.715	0.915	1412515.762	21.028
60	0.021	0.102	62460.173	6360.883	297144.025	0.878	1087891.048	17.417
65	0.032	0.147	56099.291	8230.398	260804.317	0.820	790747.023	14.095
70	0.049	0.220	47868.893	10515.664	213976.854	0.731	529942.706	11.071
75	0.079	0.329	37353.229	12285.504	156376.040	0.505	315965.852	8.459
80	0.157	...	25067.725	25067.725	159589.811	...	159589.811	6.366

Table 4.16 to Table 4.18 show life table estimates for North Central, North East and North West regions of Nigeria, derived by estimates from linking of Childhood and Adult mortality using the Coale Demeny West Model Life table as the standard. It summarizes the mortality experience at all ages with particular reference to age 20, 50 and 65 respectively. The survivorship functions (l_x) which shows the number of persons alive at above reference ages in North Central are 86075.17, 74006.62 and 57413.71 which means 86.075%, 74.006% and 57.413% live to age 20, 50 and 65 respectively and 1419, 4051 and 9288 died prior to age 25, 55 and 70 respectively, probability of dying (q_x) for those ages are 0.02, 0.05 and 0.16 respectively with expectation of life at 48.86, 24.00 and 13.46 years respectively. The expectation of life from birth in North Central region is 59 years.

The survivorship functions (l_x) for North East is 84846.244, 75530.097 and 64236.643 which means 84%, 75% and 64% live to age 20, 50 and 65 respectively and 1175, 2777 and 6623 died prior to age 25, 55 and 70 respectively, probability of dying (q_x) for those ages are 0.014, 0.037 and 0.103 respectively with expectation of life at 53.6, 28.2 and 16.7 years respectively. The expectation of life from birth in North East region is 62 years.

The survivorship functions (l_x) for North West is 81312.67, 72062.34 and 61817.40 which means 81%, 72% and 61% live to age 20, 50 and 65 respectively and 1203, 2574 and 5868 died prior to age 25, 55 and 70 respectively, probability of dying (q_x) for those ages are 0.015, 0.036 and 0.095 respectively with expectation of life at 54.25, 29.08 and 17.49 years respectively. The expectation of life from birth in North West region is 60 years.

Table 4.16: Life table estimates for North central, Nigeria

Age	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.09	0.08	100000.00	8386.68	94142.75	0.91	5970877.85	59.71
1	0.01	0.03	91613.32	2854.38	358996.38	0.97	5876735.10	64.15
5	0.00	0.01	88758.94	929.98	441469.78	0.99	5517738.73	62.17
10	0.00	0.01	87828.97	698.77	437397.90	0.99	5076268.95	57.80
15	0.00	0.01	87130.19	1055.02	433169.10	0.99	4638871.05	53.24
20	0.00	0.02	86075.17	1419.11	426937.56	0.98	4205701.95	48.86
25	0.00	0.02	84656.06	1529.70	419514.01	0.98	3778764.39	44.64
30	0.00	0.02	83126.36	1701.48	411469.22	0.98	3359250.39	40.41
35	0.00	0.02	81424.87	1977.29	402323.41	0.97	2947781.16	36.20
40	0.01	0.03	79447.58	2401.63	391449.48	0.97	2545457.75	32.04
45	0.01	0.04	77045.95	3039.33	377963.99	0.95	2154008.27	27.96
50	0.01	0.05	74006.62	4051.61	360382.06	0.94	1776044.28	24.00
55	0.02	0.08	69955.00	5343.27	337062.56	0.91	1415662.22	20.24
60	0.02	0.11	64611.73	7198.02	305901.76	0.87	1078599.66	16.69
65	0.04	0.16	57413.71	9288.21	264789.96	0.80	772697.89	13.46
70	0.05	0.24	48125.50	11557.91	212568.80	0.71	507907.93	10.55
75	0.09	0.35	36567.59	12886.46	150718.31	0.49	295339.13	8.08
80	0.16	...	23681.13	23681.13	144620.81	...	144620.81	6.11

Table 4.17: Life table estimates for North east, Nigeria

Age	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.113	0.105	100000.000	10501.052	93174.314	0.890	6292061.648	62.921
1	0.007	0.026	89498.948	2288.125	351957.420	0.975	6198887.334	69.262
5	0.002	0.010	87210.823	851.237	433926.023	0.992	5846929.915	67.044
10	0.001	0.007	86359.586	623.162	430240.027	0.991	5413003.892	62.680
15	0.002	0.010	85736.425	890.180	426574.395	0.988	4982763.865	58.117
20	0.003	0.014	84846.244	1175.729	421376.805	0.985	4556189.470	53.699
25	0.003	0.015	83670.515	1260.227	415244.744	0.984	4134812.665	49.418
30	0.003	0.017	82410.288	1383.143	408654.108	0.982	3719567.921	45.135
35	0.004	0.019	81027.145	1554.441	401335.189	0.979	3310913.813	40.862
40	0.005	0.023	79472.704	1800.770	392982.007	0.975	2909578.624	36.611
45	0.006	0.028	77671.934	2141.837	383199.214	0.968	2516596.617	32.400
50	0.007	0.037	75530.097	2777.729	371004.777	0.957	2133397.402	28.246
55	0.010	0.049	72752.369	3585.006	355230.703	0.941	1762392.625	24.225
60	0.015	0.071	69167.362	4930.720	334144.006	0.914	1407161.922	20.344
65	0.022	0.103	64236.643	6623.419	305475.549	0.873	1073017.915	16.704
70	0.034	0.157	57613.224	9052.143	266568.036	0.803	767542.367	13.322
75	0.056	0.245	48561.081	11881.209	214055.176	0.573	500974.330	10.316
80	0.128	...	36679.872	36679.872	286919.154	...	286919.154	7.822

Table 4.18: Life table estimates for North west, Nigeria

Age	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.136	0.125	100000.000	12471.631	91893.437	0.865	6082375.355	60.824
1	0.011	0.042	87528.369	3674.682	340415.979	0.964	5990481.918	68.440
5	0.002	0.011	83853.687	936.187	416927.968	0.990	5650065.939	67.380
10	0.002	0.008	82917.500	679.090	412889.776	0.991	5233137.971	63.113
15	0.002	0.011	82238.410	925.734	408988.084	0.987	4820248.195	58.613
20	0.003	0.015	81312.676	1203.509	403636.746	0.984	4411260.110	54.251
25	0.003	0.016	80109.167	1285.874	397373.364	0.983	4007623.364	50.027
30	0.004	0.018	78823.293	1408.442	390652.171	0.981	3610250.000	45.802
35	0.004	0.020	77414.851	1560.351	383247.074	0.978	3219597.829	41.589
40	0.005	0.023	75854.500	1766.311	374952.868	0.975	2836350.755	37.392
45	0.006	0.027	74088.189	2025.843	365536.022	0.969	2461397.887	33.223
50	0.007	0.036	72062.345	2574.180	354128.647	0.959	2095861.865	29.084
55	0.010	0.047	69488.165	3241.321	339706.527	0.944	1741733.219	25.065
60	0.014	0.067	66246.845	4429.438	320710.700	0.920	1402026.691	21.164
65	0.020	0.095	61817.407	5868.476	295153.099	0.883	1081315.991	17.492
70	0.031	0.143	55948.931	8028.201	260701.628	0.820	786162.892	14.051
75	0.050	0.223	47920.729	10691.806	213814.604	0.593	525461.264	10.965
80	0.119	...	37228.924	37228.924	311646.660	...	311646.660	8.371

Table 4.19 to Table 4.21 shows life table estimates for South East, South South and South West regions of Nigeria, derived by estimates from linking of Childhood and Adult mortality using the Coale Demeny West Model Life table as the standard. It summarizes the mortality experience at all ages with particular reference to age 20, 50 and 65 respectively. The survivorship functions (l_x) which shows the number of persons alive at above reference ages in South East are 85992.79, 73341.37 and 56648.93 which means 85%, 73% and 56% live to age 20, 50 and 65 respectively and 1495, 4079 and 9443 died prior to age 25, 55 and 70 respectively, probability of dying (q_x) for those ages are 0.017, 0.056 and 0.167 respectively with expectation of life at 48.24, 23.60 and 13.02 years respectively. The expectation of life from birth in South East region is 59 years.

The survivorship functions (l_x) for South South is 86896.14, 77396.01 and 64970.56 which means 86%, 77% and 64% live to age 20, 50 and 65 respectively and 1156, 3004 and 7397 died prior to age 25, 55 and 70 respectively, probability of dying (q_x) for those ages are 0.013, 0.039 and 0.114 respectively with expectation of life at 52.8, 27.2 and 15.8 years respectively. The expectation of life from birth in South South region is 63 years.

The survivorship functions (l_x) for South West is 89559.5, 80841.77 and 68041.27 which means 89%, 80% and 68% live to age 20, 50 and 65 respectively and 1013, 3013 and 7845 died prior to age 25, 55 and 70 respectively, probability of dying (q_x) for those ages are 0.011, 0.037 and 0.115 respectively with expectation of life at 53.29, 27.15 and 15.63 years respectively. The expectation of life from birth in South West region is 65 years.

Table 4.19: Life table estimates for South east, Nigeria

Age	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.083	0.079	100000	7855.387	94388.59	0.909	5915585.363	59.156
1	0.009	0.036	92144.61	3282.78	360030.7	0.972	5821196.769	63.175
5	0.002	0.011	88861.83	1007.302	441790.9	0.990	5461166.034	61.457
10	0.002	0.009	87854.53	752.947	437390.3	0.990	5019375.125	57.133
15	0.003	0.013	87101.58	1108.793	432894.4	0.985	4581984.838	52.605
20	0.004	0.017	85992.79	1495.038	426346.2	0.982	4149090.464	48.249
25	0.004	0.019	84497.75	1631.264	418478.7	0.979	3722744.223	44.057
30	0.004	0.022	82866.49	1825.809	409865.1	0.976	3304265.541	39.875
35	0.005	0.026	81040.68	2105.097	400080.5	0.971	2894400.462	35.715
40	0.006	0.032	78935.58	2510.02	388603	0.964	2494319.938	31.599
45	0.008	0.040	76425.56	3084.192	374731.1	0.953	2105716.901	27.553
50	0.011	0.056	73341.37	4079.419	356976	0.935	1730985.844	23.602
55	0.016	0.077	69261.95	5337.162	333617.2	0.906	1374009.811	19.838
60	0.024	0.114	63924.79	7275.865	302308.8	0.862	1040392.655	16.275
65	0.036	0.167	56648.93	9443.874	260626.1	0.795	738083.893	13.029
70	0.057	0.251	47205.05	11860.07	207257	0.694	477457.836	10.115
75	0.092	0.373	35344.98	13193.27	143773.5	0.468	270200.791	7.645
80	0.175	...	22151.71	22151.71	126427.3	...	126427.333	5.707

Table 4.20: Life table estimates for South South, Nigeria

Age	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.086	0.081	100000	8128.686	94260.01	0.909	6368204.510	63.682
1	0.008	0.029	91871.31	2707.619	360423.1	0.976	6273944.497	68.291
5	0.002	0.009	89163.69	804.565	443807.1	0.992	5913521.389	66.322
10	0.001	0.007	88359.13	595.142	440307.8	0.992	5469714.328	61.903
15	0.002	0.010	87763.99	867.851	436770.4	0.988	5029406.533	57.306
20	0.003	0.013	86896.14	1156.256	431677	0.986	4592636.158	52.852
25	0.003	0.015	85739.88	1246.491	425629.2	0.985	4160959.125	48.530
30	0.003	0.016	84493.39	1380.152	419084.1	0.982	3735329.900	44.209
35	0.004	0.019	83113.24	1576.126	411724.7	0.979	3316245.785	39.900
40	0.005	0.023	81537.11	1864.153	403168.3	0.975	2904521.058	35.622
45	0.006	0.029	79672.96	2276.949	392899.6	0.967	2501352.795	31.395
50	0.008	0.039	77396.01	3004.346	379814.3	0.955	2108453.167	27.242
55	0.011	0.053	74391.66	3947.334	362586.7	0.936	1728638.864	23.237
60	0.016	0.078	70444.33	5473.768	339258.1	0.906	1366052.206	19.392
65	0.024	0.114	64970.56	7397.593	307314.1	0.859	1026794.080	15.804
70	0.038	0.175	57572.97	10068.015	263903	0.781	719479.950	12.497
75	0.063	0.272	47504.95	12925.395	206101	0.548	455576.901	9.590
80	0.139	...	34579.56	34579.558	249475.9	...	249475.910	7.215

Table 4.21: Life table for South West, Nigeria

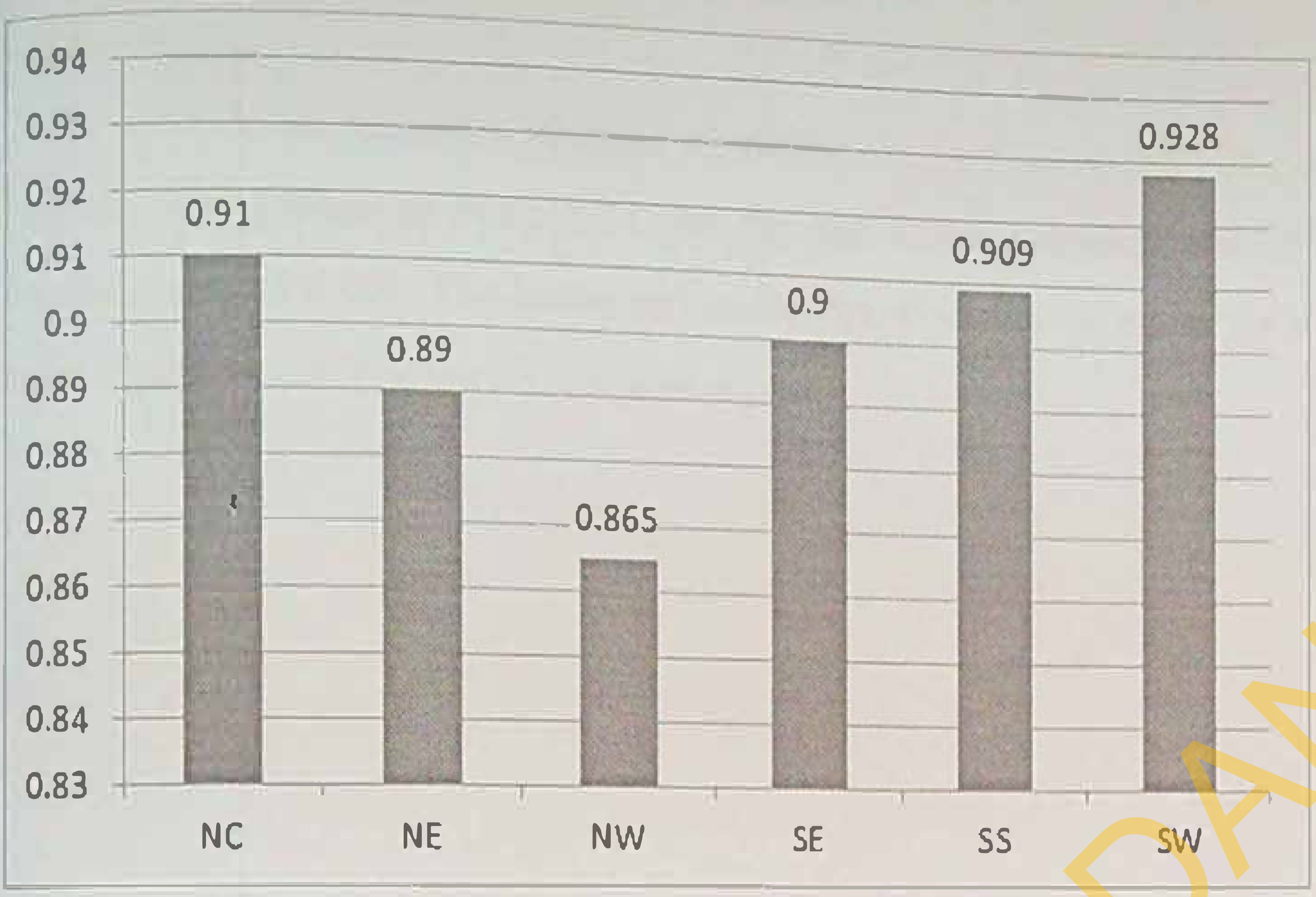
Age	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.068	0.065	100000	6474.62	95106.73	0.928	6595067.925	65.951
1	0.006	0.022	93525.38	2048.92	368812.6	0.982	6499961.193	69.499
5	0.001	0.007	91476.47	664.70	455720.6	0.994	6131148.611	67.024
10	0.001	0.005	90811.77	499.05	452811.2	0.993	5675428.035	62.497
15	0.002	0.008	90312.71	753.22	449791.7	0.990	5222616.839	57.828
20	0.002	0.011	89559.5	1013.49	445342.4	0.988	4772825.162	53.292
25	0.002	0.012	88546	1094.04	440037.3	0.987	4327482.775	48.873
30	0.003	0.014	87451.96	1220.15	434276.5	0.985	3887445.498	44.452
35	0.003	0.017	86231.81	1423.97	427704.7	0.982	3453168.979	40.045
40	0.004	0.021	84807.84	1740.86	419849.2	0.977	3025464.273	35.674
45	0.005	0.027	83066.98	2225.21	410027	0.968	2605615.056	31.368
50	0.008	0.037	80841.77	3013.53	397055.7	0.956	2195588.089	27.159
55	0.011	0.052	77828.23	4074.86	379500.1	0.936	1798532.348	23.109
60	0.016	0.077	73753.37	5712.10	355271.7	0.905	1419032.230	19.240
65	0.024	0.115	68041.27	7845.52	321642	0.856	1063760.528	15.634
70	0.039	0.178	60195.75	10740.58	275425.8	0.776	742118.515	12.328
75	0.064	0.278	49455.16	13761.22	213809.2	0.542	466692.739	9.437
80	0.141	...	35693.95	35693.95	252883.5	...	252883.495	7.085

Table 4.21: Life table for South West, Nigeria

Age	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.068	0.065	100000	6474.62	95106.73	0.928	6595067.925	65.951
1	0.006	0.022	93525.38	2048.92	368812.6	0.982	6499961.193	69.499
5	0.001	0.007	91476.47	664.70	455720.6	0.994	6131148.611	67.024
10	0.001	0.005	90811.77	499.05	452811.2	0.993	5675428.035	62.497
15	0.002	0.008	90312.71	753.22	449791.7	0.990	5222616.839	57.828
20	0.002	0.011	89559.5	1013.49	445342.4	0.988	4772825.162	53.292
25	0.002	0.012	88546	1094.04	440037.3	0.987	4327482.775	48.873
30	0.003	0.014	87451.96	1220.15	434276.5	0.985	3887445.498	44.452
35	0.003	0.017	86231.81	1423.97	427704.7	0.982	3453168.979	40.045
40	0.004	0.021	84807.84	1740.86	419849.2	0.977	3025464.273	35.674
45	0.005	0.027	83066.98	2225.21	410027	0.968	2605615.056	31.368
50	0.008	0.037	80841.77	3013.53	397055.7	0.956	2195588.089	27.159
55	0.011	0.052	77828.23	4074.86	379500.1	0.936	1798532.348	23.109
60	0.016	0.077	73753.37	5712.10	355271.7	0.905	1419032.230	19.240
65	0.024	0.115	68041.27	7845.52	321642	0.856	1063760.528	15.634
70	0.039	0.178	60195.75	10740.58	275425.8	0.776	742118.515	12.328
75	0.064	0.278	49455.16	13761.22	213809.2	0.542	466692.739	9.437
80	0.141	...	35693.95	35693.95	252883.5	...	252883.495	7.085

Figure 4 shows the survivorship probability across the six geopolitical zones; there were variations in probability of survival from birth among the zones. South West had the highest survivorship probability of 0.928 and North West had the lowest survivorship probability of 0.865. The probability of surviving in North Central is 0.91, probability of surviving in North East is 0.89, probability of surviving in South east is 0.90 and probability of surviving in South South is 0.909.

Figure 4: Comparison of survivorship probability across the six geopolitical zones



4.4 ESTIMATION OF PROBABILITY OF DEATH AT CHILDHOOD USING THE HELIGMAN POLLARD MODEL

Table 4.22 shows estimates of child mortality obtained using the Heligman Pollard Model for Nigeria. The Heligman Pollard Model showed infant mortality rate of 0.092 and under-five mortality rate of 0.102. The infant and under-five mortality estimates for Nigeria indicates a high level of childhood mortality in the country.

Table 4.22: Heligman Pollard model estimates of child mortality in Nigeria

Age	$q(x,n)$	*Parameter A*	*Parameter B*	*Parameter C*	q_x
0	0.106	0.105	0.07	0.99	0.092
5	0.138	0.105	0.07	0.99	0.102

Table 4.23 to Table 4.25 shows estimates of childhood mortality obtained using the Heligman Pollard Model for North Central, North East and North West regions of Nigeria. The Heligman Pollard Model showed infant mortality rate of 0.075, 0.089 and 0.106 for North Central, North East, North West zones respectively. Infant mortality rate is highest in North Western Nigeria with an infant mortality rate of 0.106 and lowest in North central Nigeria with an infant mortality rate of 0.075. The infant mortality estimates for Northern Nigeria indicate a high prevalence of infant mortality in these regions. The under-five mortality rates given by the model in the regions are 0.081, 0.098 and 0.120 for North Central, North East and North West regions respectively.

Table 4.23: Heligman Pollard model estimates of child mortality in North Central, Nigeria

Age	*q(x,n)*	*Parameter A*	*Parameter B*	*Parameter C*	q_x
0	0.083	0.083	0.05	0.99	0.075
5	0.112	0.083	0.05	0.99	0.081

Table 4.24: Heligman Pollard model estimates of child mortality in North East, Nigeria

Age	*q(x,n)*	*Parameter A*	*Parameter B*	*Parameter C*	q_x
0	0.105	0.105	0.080	0.99	0.089
5	0.127	0.105	0.080	0.99	0.098

Table 4.25: Heligman Pollard model estimates of child mortality in North West, Nigeria

Age	*q(x,n)*	*Parameter A*	*Parameter B*	*Parameter C*	q_x
0	0.125	0.124	0.08	0.992	0.106
5	0.161	0.124	0.08	0.992	0.120

Table 4.23: Heligman Pollard model estimates of child mortality in North Central, Nigeria

Age	$q(x,n)$	*Parameter A*	*Parameter B*	*Parameter C*	q_x
0	0.083	0.083	0.05	0.99	0.075
5	0.112	0.083	0.05	0.99	0.081

Table 4.24: Heligman Pollard model estimates of child mortality in North East, Nigeria

Age	$q(x,n)$	*Parameter A*	*Parameter B*	*Parameter C*	q_x
0	0.105	0.105	0.080	0.99	0.089
5	0.127	0.105	0.080	0.99	0.098

Table 4.25: Heligman Pollard model estimates of child mortality in North West, Nigeria

Age	$q(x,n)$	*Parameter A*	*Parameter B*	*Parameter C*	q_x
0	0.125	0.124	0.08	0.992	0.106
5	0.161	0.124	0.08	0.992	0.120

Tables 4.26 - 4.28 show estimates of child mortality obtained using the Heligman Pollard Model for South East, South South and South West regions of Nigeria respectively. The Heligman Pollard Model showed infant mortality rates of 0.072, 0.072 and 0.058 for South East, South South and South West regions respectively. South West has the lowest infant mortality rate in the Southern region of the country. The under-five mortality estimates given by the model in the regions are 0.077, 0.078 and 0.062 for South East, South South and South West regions of Nigeria respectively.

Table 4.26: Heligman Pollard model estimates of child mortality in South East, Nigeria

Age	*q(x,n)*	*Parameter A*	*Parameter B*	*Parameter C*	q_x
0	0.079	0.078	0.043	0.991	0.072
5	0.111	0.078	0.043	0.991	0.077

Table 4.27: Heligman Pollard model estimates of child mortality in South South, Nigeria

Age	*q(x,n)*	*Parameter A*	*Parameter B*	*Parameter C*	q_x
0	0.081	0.081	0.052	0.993	0.072
5	0.108	0.081	0.052	0.993	0.078

Table 4.28: Heligman Pollard model estimates of child mortality in South West, Nigeria

Age	*q(x,n)*	*Parameter A*	*Parameter B*	*Parameter C*	q_x
0	0.065	0.064	0.043	0.995	0.058
5	0.085	0.064	0.043	0.995	0.062

Figure 5 compares infant mortality estimates obtained from the Heligman Pollard model across the six geopolitical zones. Infant mortality rate was highest in North West region with a mortality rate of 0.106 and lowest in South West region with an infant mortality rate of 0.058. The infant mortality rate in North Central was 0.075; infant mortality rate was 0.089 in North East, 0.072 in South East and 0.072 in South South.

Figure 5: Comparison of Heligman Pollard infant mortality estimates across the six geopolitical zones

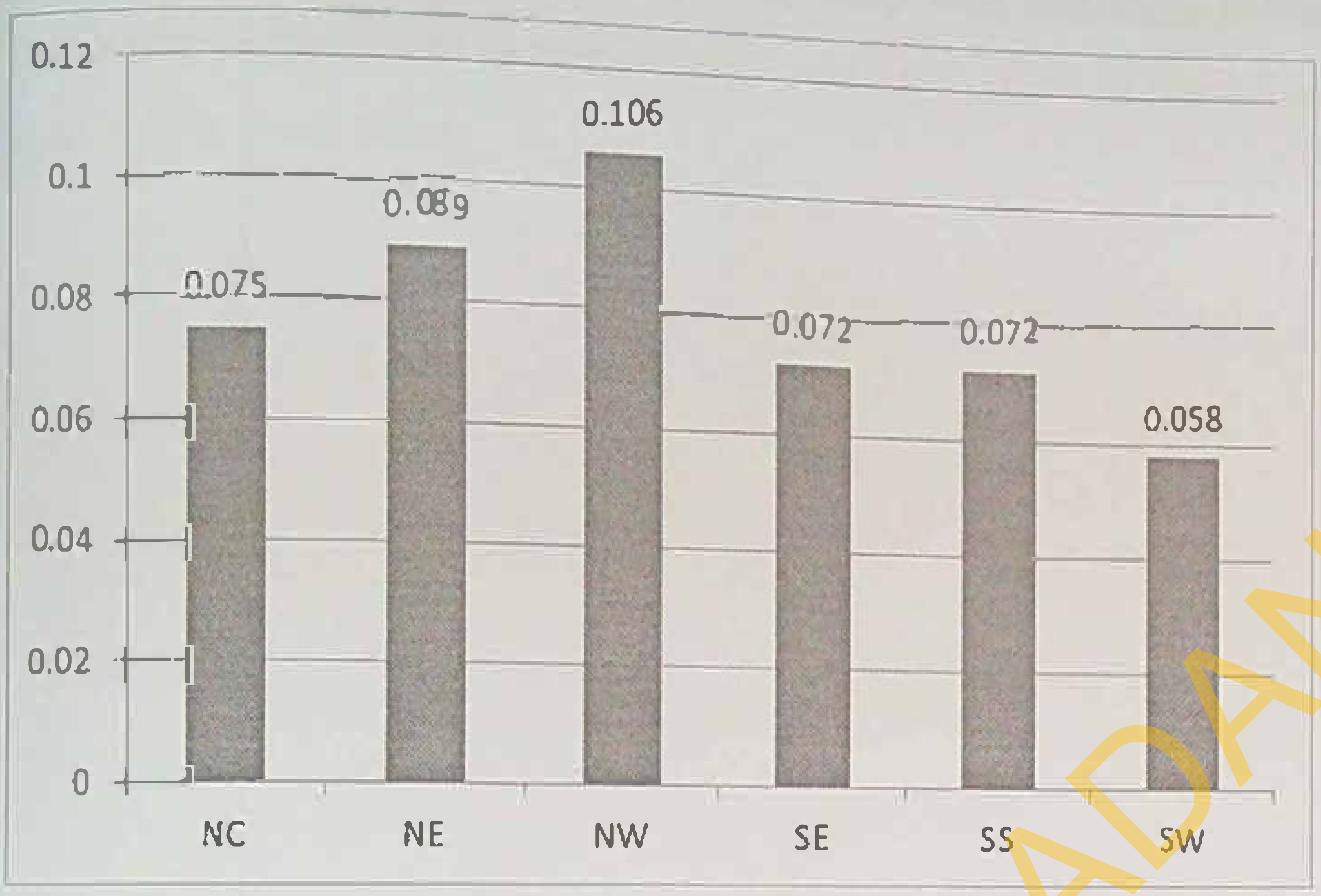


Figure 6 shows the comparison under-five mortality estimates obtained from the Heligman Pollard model for the six geopolitical zones. Under-five mortality rate was highest in North West with a mortality rate of 0.120 and lowest in South West with under-five mortality rate of 0.062. Under-five mortality rate in North Central was 0.081, 0.098 in North East, 0.077 in South East and 0.078 in South South.

Figure 6: Comparison of Heligman Pollard under-five mortality estimates across the six geopolitical zones

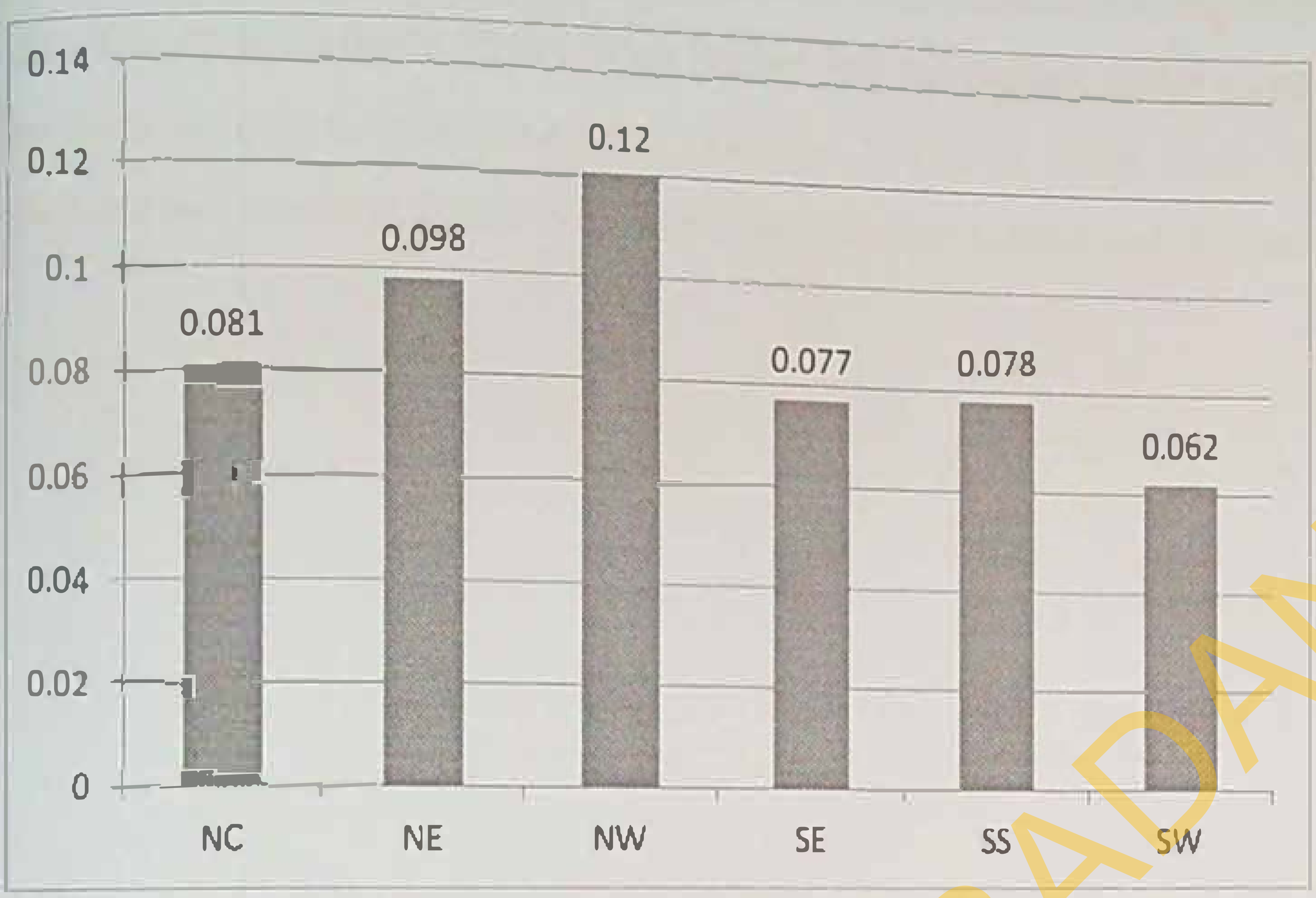


Figure 7 compares the relationship between infant mortality estimates obtained from Brass method, Life table method, Heligman Pollard model and NDHS report across the six geopolitical zones. Infant mortality estimates obtained from Brass method was higher than estimates obtained from the other methods. North West region had the highest infant mortality rates from all the methods examined. Infant mortality rate was lowest in South South from NDHS and Brass methods and lowest in South West from the Life table method and Heligman Pollard model.

Figure 7: Comparison of infant mortality estimates from Brass, Life table, Heligman Pollard model and NDHS across the six geopolitical zones

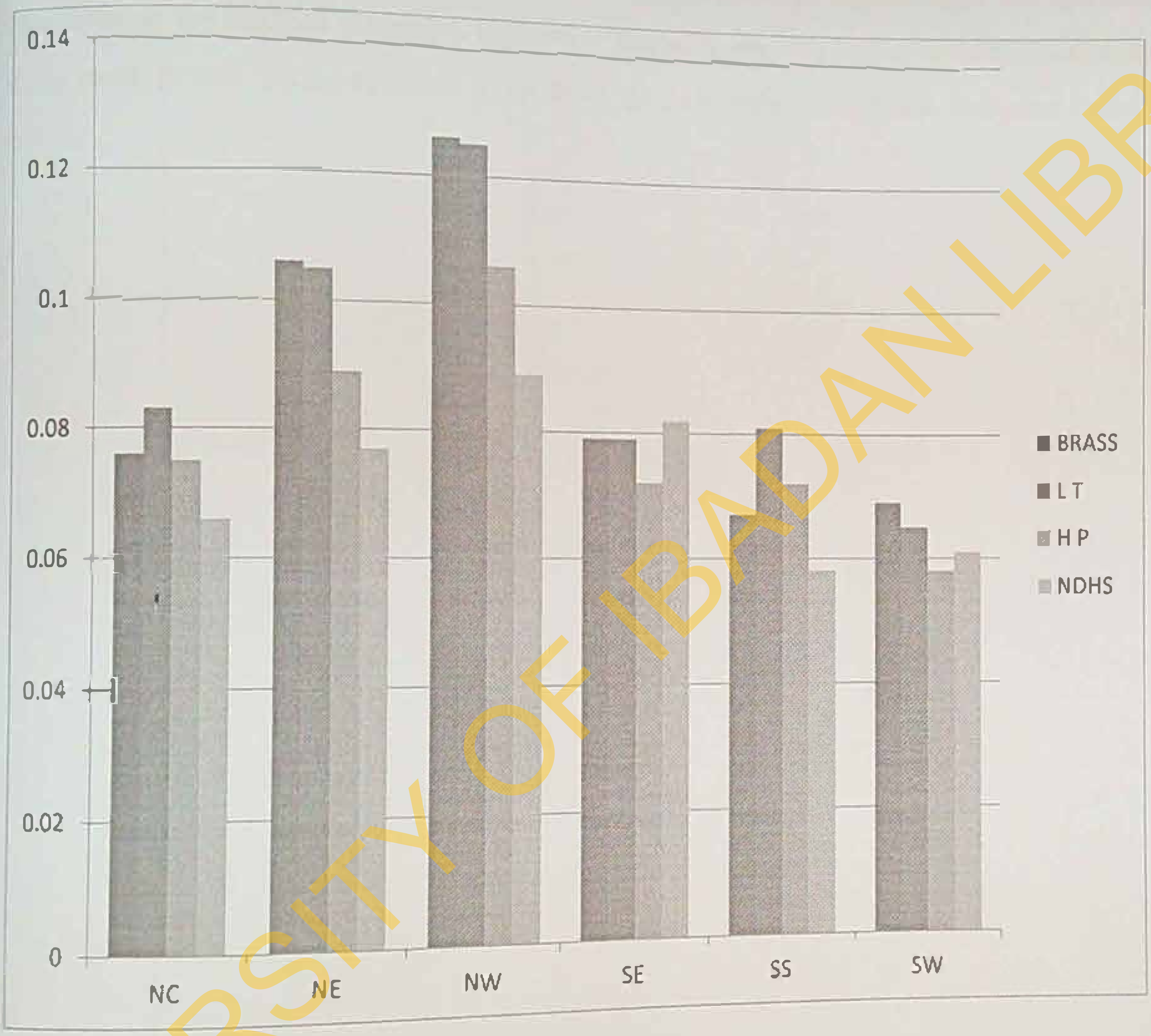


Figure 7: Comparison of infant mortality estimates from Brass, Life table, Heligman Pollard model and NDHS across the six geopolitical zones

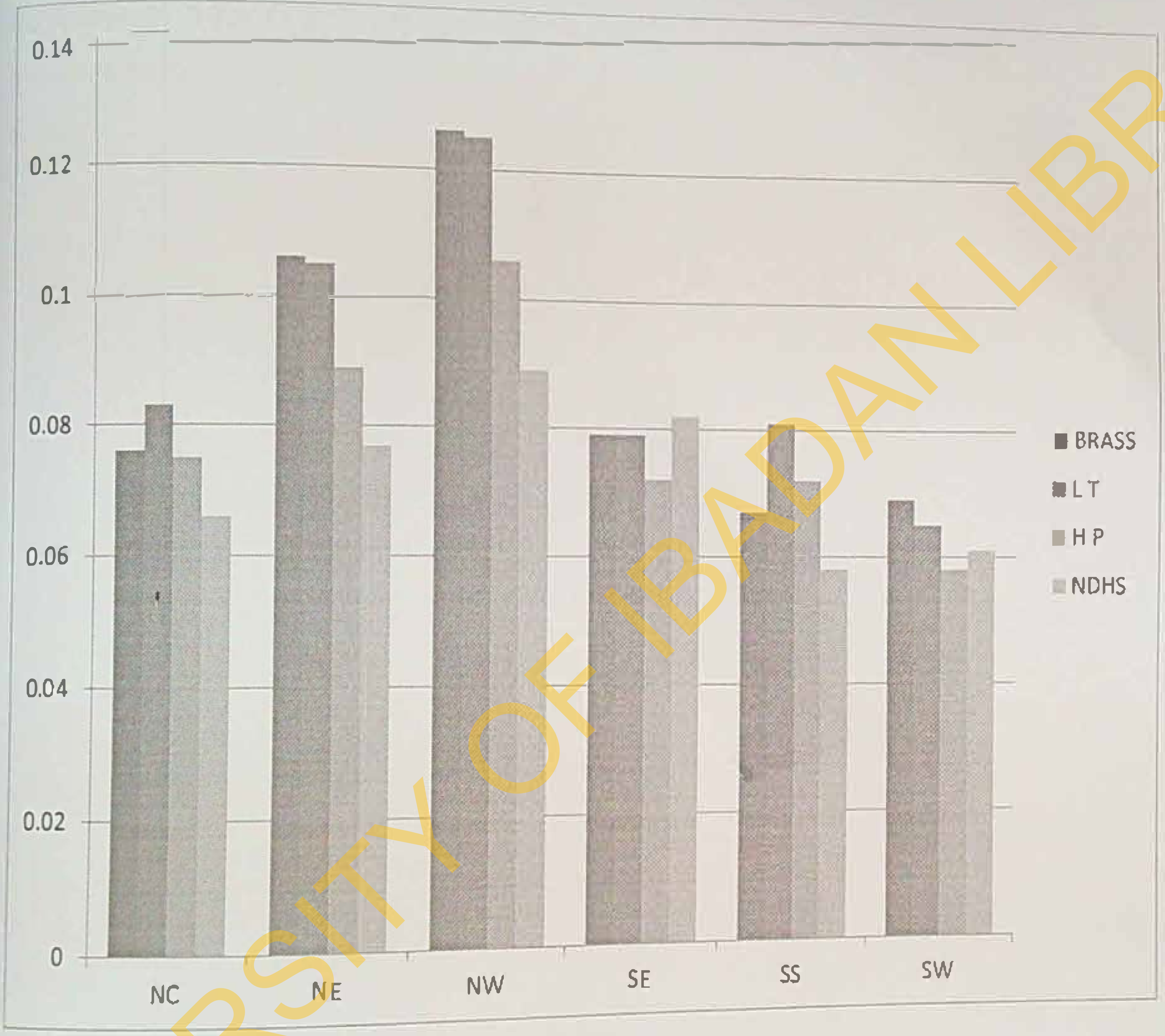
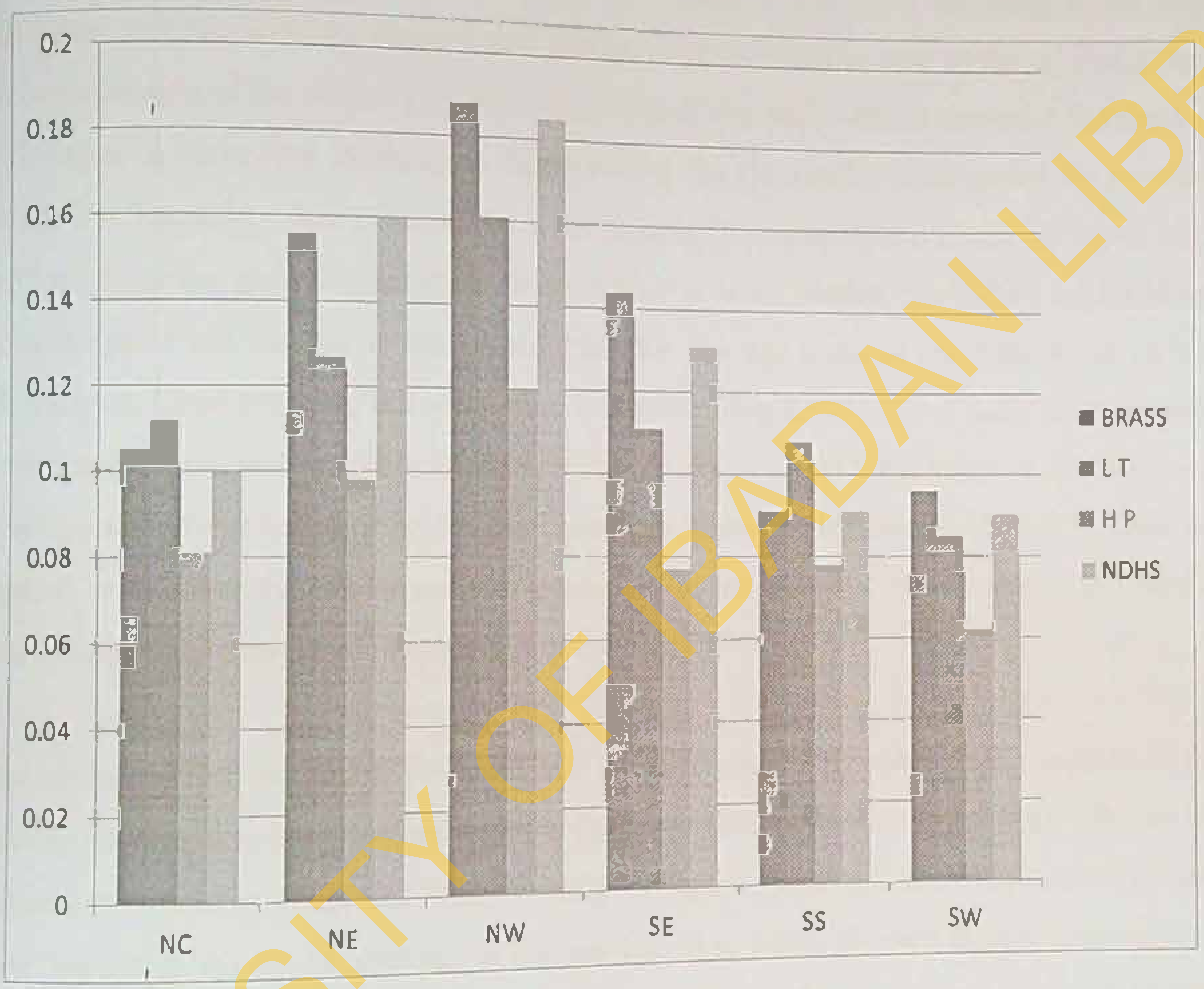


Figure 8 shows the comparison of under-five mortality estimates obtained from Brass method, Life table method, Heligman Pollard model and NDHS report across the six geopolitical zones. Under-five mortality estimates obtained from Brass method was higher than estimates obtained from the other methods in most regions. North West region had the highest under-five mortality rates from all the methods examined. Under-five mortality rate was lowest in South South from Brass methods and lowest in South West from the Life table method and Heligman Pollard model.

Figure 8: Comparison of under-five mortality estimates from Brass, Life table, Heligman Pollard and NDHS across the six geopolitical zones



CHAPTER FIVE

DISCUSSION AND CONCLUSION

5.1 DISCUSSION OF FINDINGS

This chapter puts forward the discussion of the findings of this study according to the study objectives together with the strength and limitation of the study as well as the conclusion and recommendation of the study. The major objective of this study was to determine the regional differences in under-five mortality in Nigeria using the Heligman Pollard model for mortality estimation. Secondary data extracted from the Nigeria Demographic and Health Survey of 2013 were used for the study. Information on children ever born, number of children dead, siblings alive at age 15 and number of siblings dead for five year age group of respondents was used in the analysis. Child mortality estimates were computed using Brass method, adult mortality rates were derived from siblings method proposed by Timeus et al 1997. Estimates of childhood and adult mortality were linked using the Logit life-table system as presented in Manual X. Thus, the studied focused on the use of indirect techniques of demographic measurements to estimate mortality patterns prevalent in the regions of the country.

The study revealed variations in infant and under-five mortality rates among regions in the country and this was in agreement with the findings of the study by Adedini et al, 2015 on the regional variations in infant and child mortality in Nigeria. Infant and under-five mortality rates were highest in the North western region and lowest in South Western region. Generally the Northern regions were at higher risk of infant and under-five mortality among all regions examined. This could be attributed to poor socioeconomic status and poor community level characteristics in these areas (Adedini et al, 2015).

They were also variations in expectation of life across the regions, life expectancy from birth (e^0) was highest in South West and lowest in North Central, the probabilities of surviving from birth was highest in South West and lowest in North west while probability of dying (qx) was higher in the North than the Southern regions. The mortality table functions showed higher mortality levels and lower survival rates in the North than the Southern regions. The study also revealed that the probability of surviving slightly increases after infancy till age ten and then drops gradually as age increases till the end of the life table and same trend applies to expectation of life.

The Heligman Pollard model was considered because recent studies with the model in other populations have shown that it is the best existing demographic model for estimating mortality at all ages (Ibrahim 2008, Sharrow et al, 2013) Furthermore, the model possess parameters which have demographic interpretation (Heligman and Pollard 1980, Rogers and Gard 1991). In estimating mortality rates using the Heligman pollard model, mortality estimates were first obtained using Brass method, Siblings method and Life table methods. Although the Brass and Life table methods yielded plausible results, the estimates obtained were different from estimates obtained using the Heligman Pollard model. The mortality estimates obtained using the Heligman pollard model was also different from the estimates obtained from the Demographic and health survey of 2013. Infant and under-five mortality given by the Heligman Pollard model was highest in North West and lowest in South West gegion.

The Brass estimates of child mortality showed that Nigeria has high infant and child mortality rates proved by the high probability of death prevalent in most zones. These high mortality rates were also present in all the methods applied and are in agreement with the study by Adebowale et al, 2017 on Predictors of under-five mortality in Nigeria. The study also found a similarity in the age pattern of mortality among the methods used. In most of the zones examined; the probability of dying decreased after the first year of life and survival rates fall noticeably as age increases. In the adult mortality estimation, the proportion of siblings still alive and proportion that survived to age 15 who are still alive at age n decreased with increase in age. Furthermore, the estimated survival probabilities derived from estimates of under-five mortality rates were approximately similar to the life table survivorship probabilities. The probability of dying at infancy is lower in the National Demographic and Health Survey report than in the methods of estimation examined.

In all zones, most children were exposed to high mortality rates through the childhood ages. The Heligman Pollard model shows estimates that varies with the Brass model of child mortality estimation, mortality estimates of Brass method was higher than the Heligman Pollard model estimates. Recent studies on childhood mortality modeling using the Heligman Pollard model that used Health Survey data showed that there was vivid increase in child mortality but that was attributed to high prevalence of HIV (Sharrow et al. 2013). Also from recent studies and reports on the Heligman Pollard model, the model provides more reliable estimates of the risk of death in the study populations. Thus, results of this study have shown that the Heligman Pollard model is efficient when used with secondary data and it provides accurate estimates of mortality at early life.

5.2 LIMITATIONS AND STRENGHTS OF THE STUDY

The reporting of under-five mortality by women may include omission of few deaths since child deaths are seen as bad events that they do not want to remember. Inability of the respondents to report deaths correctly may lead to response and recall bias since the records of death are based on reports given by sampled respondents. These biases may affect the true level and pattern of mortality in the population. Also misclassification of and infant deaths and stillbirths is also possible, particularly in settings where misclassification was purposeful in order to avoid death registration. Due to security challenges, some clusters in the Northern part of Nigeria were omitted during the 2013 demographic and health survey. These factors outlined could collectively distort the true pattern of mortality in recent times in the population under study. But this study utilizes indirect techniques of demographic estimation which minimize such errors.

A major strength of this study is that it utilizes a nationally representative dataset which accounts for sampling design effects (the study samples were effectively selected from the larger population). This study derived life tables for Nigeria and its geopolitical zone and presents the true infant mortality situation in the country, an indices useful for efficient planning of health and development to improve general wellbeing of the citizens of the country particularly the vulnerable population.

5.3 CONCLUSION

It was discovered that the estimated probabilities of death obtained in the study follow the general age pattern of mortality. Thus, probabilities of dying initially fall swiftly as age increases; but increases again with further increase in age. At older ages, the probabilities of dying increases again but now more progressively, indicating higher mortality levels at older ages. However, both child and adult mortality estimates are needed to estimate a good survival function and life tables and a plausible survivorship probability can be derived by linking estimates of childhood and adult mortality. Under-five mortality rate was also found to be higher in the Northern regions compare to the Southern regions. The Nigeria demographic and health survey yielded lower under-five mortality estimates than the Heligman Pollard model. Thus, it can be concluded that methodology adopted by the health surveys, as good as it may be, still under-estimates mortality rates in the population.

5.1 RECOMMENDATIONS

Based on the findings of this study, the following are recommended:

Due to the high level of child mortality obtained in this study, programmes that target the alleviation of child mortality in Nigeria should be improved.

Due to the variation in the level of mortality produced by different models previously used in Nigeria, it could be important to have a unique model that would provide more accurate childhood mortality estimates in Nigeria.

Although the Heligman Pollard model provided higher estimates of childhood mortality than previous models used in Nigeria, the use is however recommended because of its high credibility.

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APPENDIX I

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