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Ntozi, JPM

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THE DETECTION AND ADJUSTMENT OF AGE ERRORS IN DEMOGRAPHIC DATA FROM AFRICA AND OTHER DEVELOPING REGIONS

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Thesis Submitted for the Degree of
Doctor of Philosophy in Medical Demography

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March 1977

ABSTRACT OF THESIS

Age data collected in demographic surveys and censuses in Africa and other developing regions are defective and incomplete. The reasons for these limitations are discussed in the thesis and methods of detecting and adjusting for the errors in age and coverage are presented, tested and applied.

The uses of age data, the sources of age and coverage errors and some of the previous attempts at reducing the errors at the collection and analysis stages in developing countries are considered. Furthermore, an examination of age heaping in tropical African censuses is made, and the resultant patterns are discussed. In addition, the study uses an averaging method to classify age and coverage errors in tropical African surveys and censuses into four patterns. The plausibility of these four error patterns is examined and discussed and cogent evidence is presented to show that they exist. An orphanhood method is used to examine the question of sex differentials of the errors but the result is not conclusive.

Since two or more successive censuses in a single country have become available in many developing regions, the study presents, tests, and applies methods that utilise age data collected at consecutive censuses in order to examine and adjust for age and coverage errors. The possible application of the Demeny-Shorter method to age data from Africa, where conditions are different from those in Turkey, is discussed. The Demeny-Shorter method is difficult to apply directly, so a method based on the same idea as Demeny-Shorter method, but utilising age data from three, instead of two, successive censuses is presented and discussed as a possible alternative. This three-census method is applied to data from the

Fiji Islands, Mexico and Turkey censuses, and found to be better than the Demeny-Shorter method because the former allows for and estimates the likely changes in census coverage and different patterns of age errors in successive censuses. Unfortunately, the method can not be applied to data from Africa on account of lack of the requisite data.

Next, a method that uses percent age distributions from two successive censuses is developed in order to estimate the trend of real fluctuations in a population, and by use of this estimated trend the age data collected at quinquennial and decennial censuses are adjusted and split into smaller groups. The method is successfully applied to data from Africa, the Fiji Islands, Mauritius, Mexico and Turkey.

The conclusions to be drawn from the study are that (i) there are several patterns of age heaping in tropical Africa; (ii) there is strong evidence to support the existence of at least four patterns of age and coverage errors; (iii) there is little evidence to suggest distinct sex differentials of age and coverage errors; and (iv) that the methods that use data from two or more censuses are to be preferred.

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ACKNOWLEDGEMENTS

It would have been impossible for me to accomplish the work in the thesis without help from others. I wish to express my deepest gratitude to Professor W. Brass for kindly supervising my study. His guidance included suggesting ideas on the techniques in the study, giving advice on the application of the methods and offering useful criticism on the preliminary drafts of the thesis. My thanks also go to Dr. J.C. Barrett who advised me on the computer work of the study, read the preliminary draft of the thesis and suggested valuable alterations. I am indebted to Dr. J.C.C. Blacker for supplying me with some of the data on orphanhood in Africa, and to Mr. J. Hobcraft for allowing me to use his computer program. Also to be acknowledged are the services of the staff of the computer terminal of the London School of Hygiene & Tropical Medicine for solving my computing problems. The typing of this thesis was done by Miss D. Boyes to whom I am very grateful. The Staff and research students, especially Mr. K. Ersoy, Mr. Md. Kabir and Mr. M. Khan, of the Centre for Overseas Population Studies are thanked for their kind cooperation and encouragement during my stay at the Centre.

The Study was financed by Makerere University Staff Development Committee to whom I am very much indebted. Also special thanks go to Dr. Tulya-Muhika, the Director of the Institute of Statistics and Applied Economics, Makerere University, and Professor Kpedekpo, my MSc. supervisor for arranging my sponsorship in London.

My special love and thanks go to my wife, Ida, without whose patience, encouragement and cooperation my research would have taken much longer to complete.

CHAPTER ONE

INTRODUCTION

1.1 Uses and defects of age data.

Age is of fundamental importance in describing and analysing demographic phenomena. Data on age are generally useful in three ways. Firstly, age data are used in the analysis of fertility, mortality, nuptiality and many other areas of demography. Secondly, age is important in socioeconomic planning. For example, tabulations on age are essential in computations of basic measures relating to factors of population change, in the analysis of the factors of labour supply, and in the study of the problem of economic dependency. It is necessary to know how many children are under age five in a population in order to plan for the number of schools to be built for them; and how many people are in old age in order to plan pension schemes and geriatric hospital beds for them. Thirdly, census data by small age groups are very necessary for projection purposes. Because of these uses, it is essential that age data are as correctly enumerated as possible.

Unfortunately, in most developing countries age data collected so far are highly inaccurate. For instance, age data collected in all past demographic surveys in tropical Africa are known to be defective. There are several main causes of errors in these age data. Perhaps the biggest cause of age errors is ignorance and illiteracy. This cause of error has been summed up by Dr. Blacker (1971) when he observes, "The widespread ignorance of age in the number of completed years bedevils the collection of accurate data, and studies which have been made of reported African age distributions have revealed massive and deep seated errors "; and by the United Nations (1961,p.243) which evaluated the South Asian situation as, "It would appear that the Indian population is not traditionally age conscious". With this kind of ignorance of age, the traditional questions on age - 'How old are you?' and 'When were you born?' cannot be expected to receive accurate response in most developing countries.

Even in populations which are neither ignorant nor illiterate, as in the United States or in Western Europe, age errors have been detected in the past censuses. Much of these census age errors have been traced in heaping on certain digits, mostly on digit 5 and 0, by respondents. This type of error tends to be more serious with older ages. This age heaping problem is much worse in developing countries where ignorance and illiteracy exacerbate the situation.

The third cause of age errors in developing countries is wilful intention. Sometimes, where the respondents are neither too ignorant nor too illiterate to remember their actual ages, they may deliberately report false ages. Their intentions in doing this may stem from the wish to avoid taxation or military conscription by reporting themselves younger or older than the legal age range. On the other hand, some respondents may want to take advantage of the social benefits of the system by, say, reporting themselves older, in the case of men, to gain respectable status in the society; or younger, in the case of women, to look attractive in society.

Fourthly, some of the age errors are introduced into the data by the census enumerators and interviewers. Censuses and national sample surveys are too big to allow the organisers to give adequate training to their enumerators and interviewers who are the primary collectors of the age data. Furthermore, enumerators do not have enough time to probe for the

the correct age and most of them use their judgement, which is quicker than using instructions laid down. In such situations, the enumerators are tempted to assess respondents' ages by using norms like age at puberty, marriage or menopause, parity and physical appearance. All these characteristics are merely rough guides of age and often mislead the enumerator into recording totally wrong ages since there is great individual variability in the relation between these characteristics and age.

A fifth source of age errors in developing countries is defective age data collection procedures. Some of the age errors are caused by the wording of questions. The 'date of birth' question creates problems of ignorance, while the question of 'How old were you at the last birthday?' may be irrelevant in societies which do not celebrate their birthdays and hence have no social need to remember them. Both these questions tend to give rise to digit preference. For example, 'date of birth' question resulted in a marked preference for digit 9 in the Rhodesian African and Zambian censuses of 1969 because respondents rounded up their dates of birth at years ending in 0 like 1910, 1920, 1930 etc.; while the 'How old are you?' question led to heaping of ages on digits 0 and 5 in the Ugandan and Kenyan censuses of 1969.

The final cause of age errors is the difference of age scales in different societies. Since the organisers of censuses and demographic surveys in most developing countries were either from the western countries or trained there, they have tended to use age scales that are alien to the population surveyed. For instance, the western concept of solar calendar years is different from the concepts in many societies in the developing countries. Some societies in Africa work with season or moon calendars, while the Chinese use 'animal' calendars; and the Japanese idea of counting ages is a year ahead of the western counting.

Apart from the age errors, the age data collected in developing countries are deficient because of coverage errors. The omissions in the census or survey may be so significantly big that the reported age structure is not representative of the actual population even if the mis-statements were small. Coverage errors may be due to several factors. Firstly, migrations cause many omissions. On the census night there are internal migrants who are not covered. If the census is de jure, many emigrants are missed because they are illegal; for instance, in Upper Volta a study done on emigrants to Ghana (see Conde 1971 Table IV-4D) found that those reported in Upper Volta were only 43% of the Upper Volta's citizens enumerated in Ghana around the same time because many were not reported by their families for fear of prosecution in case they were illegally outside the country. Furthermore, some of the censuses in Africa, like those in the Portuguese and South African controlled areas taken on the administrative assembly basis, did not cover everyone; women and children were liable to omission. In addition, some societies in the developing world are prohibited by custom from reporting on certain age groups because of religious and cultural reasons. For example, many men in the Arab and Muslim African areas do not allow enumerators to meet their wives. Also some African societies have cultures which prohibit anything tantamount to counting children. Consequently, many wives and children might have been missed by censuses. Boundary problems and wars have also contributed to omission errors. For instance, the 1962 Kenyan census left about one fifth of the country's land unenumerated because of the boundary clashes between Kenyan and Somalian soldiers at the time. Besides, some areas in Africa are inaccessible. Parts of Lesotho were too inaccessible to be enumerated in the 1966 census. Nomadic life in some African countries makes it impossible to enumerate fully populations of certain areas; for example, the Turkanas and the Karamajong of Kenya and Uganda were only partially covered in the last censuses because they lead pastoral lives. Also, many areas of Chad and Upper Volta were left out because it was impracticable to enumerate the nomads. Lastly, it must be noted that the coverage errors distort the percentage age structure in so far as the age structure of the missed groups is different from the rest of the population. This is particularly likely to happen in a country where there is much internal migration, either of a long or short term nature.

1.2 Procedures of probing for improved age data.

Some of the age errors mentioned above arise from the use of the traditional questions on age (i.e. asking straight questions on date of birth or completed years). The major problem of asking the question on the date of birth in Africa is that most people do not celebrate their birthday, and thus, it is often useless to ask for the day or month of birth; but if a year of birth only is asked there is a problem of deciding which age a person is if a census is held in the middle of a year. However, of the two questions, many experienced demographers in Africa (e.g. J. Blacker and C. Scott - 1974, p.39) prefer the 'date of birth' to 'completed years' because of three reasons: (1) a date of birth is fixed and hence less confusing to remember than the age which varies from year to year; (2) probing for year of birth may encourage the enumerators to make use of event calendars or other aids; (3) those respondents with birth or baptism certificates may be encouraged to utilise then if asked to give date of birth.

In order to improve the quality of the collected age data, several procedures of age probing have been used in different inquiries of the developing countries. The best known and most widely used method for helping enumerators to probe for ages of respondents is the historical event calendar. The event calendar method has not been very successful in pinpointing the actual date of birth mainly because there has been a tendency for the census organisers to emphasise national events which often have meant little to the rural population. For instance, a national event like political independence is easily common knowledge to the educated people in Africa, but may not be remembered by most rural people who are apolitical and remote from the centre of political activities. It is possible to make local event calendars, but such exercises would be too expensive and time consuming. In addition, enumerators need sufficient motivation, rigorous training and adequate time to be able to use the calendars satisfactorily. In censuses and big surveys, these requirements are very difficult to satisfy because of costs and lack of time. Another drawback of the event calendar system is that if enumerators put the historical events in a form of leading questions to respondents, the latter are encouraged to simply acquiesce either out of politeness or in order to avoid further boring questions which may expose their ignorance. Besides, the respondents may confuse events which occurred next to one another, for example, influenza epidemics may be confused with, say, smallpox epidemics or drought with famine.

A further procedure of probing age is the use of tribal age grades. For example, Dr. Blacker used age grades based on special names for those who underwent circumcision in the same period in the Kikuyu of Kenya. This procedure may be advantageous in that since most people asked answer immediately and clearly, there is no further probing required. However, the procedure is of limited value because: firstly, many tribes in Africa do not have age grade systems; secondly, some age grades may be so broad as to be useless for enumerating ages in small age groups; thirdly, local variations may be too many for any meaningful general age grade system to be constructed for an area; and finally, migrations and intermingling of peoples from different cultural traditions can make the procedure difficult to apply.

Another procedure of age collection has been suggested by Caldwell and Igun (1971). It is based on the idea that if people (usually the literate and educated) in a locality know their ages accurately, their ages would be used as benchmarks in the estimation of ages of other respondents who are in the contemporary cohorts. This approach has been used unsystematically in small anthropological studies. Although the development of a systematic procedure is still at the experimental stage, it appears to be of limited value because of the extra time and expense required that seem to be unjustified because of the marginally better results obtained so far.

Lastly, there have been suggestions of the use of specific characteristics of physical development in estimating chronological age. For instance, Voors (1957) and Voors and Matselar (1958) made studies on the relationship between dental and chronological age. Such procedure has not been used in censuses and more tests may be necessary to show the effect of the variability on biological aging among individuals in homogenous populations. In fact, enumerators and interviewers have long used the physical features of respondents to determine age in many demographic surveys where age is completely unknown, but the resulting errors are erratic and uncontrollable. Often age reports have been based on cultural factors such as weaning, walking, talking, puberty and marriage.

1.3 Existing methods of analysing defective age data

Whilst field demographers were trying out new procedures for improving the quality of the collected data, another group of demographers was working on methods of analysing the defective reported age data. The works of the latter group include studies by A.J. Coale, P. Demeny, Norman Carrier, John Hobcraft, E. Van de Walle and A.M. Farrag.

The theory of stable population, which was first conceived by Euler in 1760 and fully developed by Lotka in 1907, has been expanded and used extensively by demographers in analysing age data. The age distribution of a stable population is given by the equation:

$$c(a) = be^{-ra} p(a) \qquad (1.1)$$

where c(a) is the proportion of the population at age a, b is the birth rate, p(a), the proportion surviving from birth to age a and r is the annual rate of increase. r is the sole real root of equation:

$$\int_{o}^{w} e^{-ra} p(a) m(a) da = 1 \qquad (1.2)$$

where m(a) is the proportion of persons of one sex who annually become parents of a child of the same sex, and w is the highest age attained.

Using the fact that every combination of a life table and a rate of increase determines an age composition with an associated birth rate and death rate, Coale and Demeny produced a total of nearly 5,000 stable populations associated with 192 model life tables (24 for each sex of four regional families). Three of the four regional families of life tables (North, East and South) are wholly based on mortality experience found in the Northern, Eastern and Southern parts of Europe, and the fourth family (West) mostly on Western Europe, but also on the White Commonwealth, South Africa Whites, U.S.A., Japan, Taiwan and Singapore. These model stable population age distributions have been used widely for many countries where age data are incomplete, but there is no evidence to indicate that underlying age structure has approximately followed quasi-stable population conditions, i.e. falling mortality and approximately constant fertility. However, the main disadvantage of the Coale-Demeny stable age distributions is that they are based on European life table systems, which are unlikely to exhaust the variety of mortality patterns to be found in the world. For instance, some developing countries have higher rates of infant and early childhood mortality and a faster declining tempo of these rates than envisaged in the tables.

A more flexible set of model stable population age distributions was calculated by Carrier and Hobcraft (1971) from the Brass model life table systems. The Brass model life table systems depend on the logit transformation equation:-

$$Y(x) = \alpha + \beta \; Ys(x) \qquad (1.3)$$

which relates the standard mortality function $\ell s(x)$, to the other schedules of mortality, $\ell(x)$, and where $Ys(x)$ and $Y(x)$ are logits of the former and latter functions, respectively. α and β are constants - α measuring the level of the overall mortality and β, the relation between child and adult mortality. Brass (Brass et al.,1968 pp.127-135) has indicated that this two-parameter (α and β) becomes one parameter (α only varies) life table system whenever there is insufficient evidence about adult mortality to justify a choice of β other than $\beta = 1$. The 'African Standard' is a special case of these life tables, where $\beta = 1.0$ and $\alpha = 0.0$, features that approximate to the mortality situation in Africa.

The calculation of the two parameter stable population tables by Carrier and Hobcraft was based on the Brass one parameter model life table system to represent the mortality conditions and on the Gross Reproduction Rate (GRR) to represent fertility conditions. One Carrier-Hobcraft table is allocated to each mortality level, from level 0 to 90 by steps of 5. For each mortality level there are 16 age distributions reflecting 16 fertility assumptions made, i.e. representing GRR's of 1.0 to 4.0 by steps of 0.2. These tables are flexible and have been much used by demographers in the analysis of incomplete age data from developing countries.

In addition to these two model stable population systems, other studies of age data specific to particular situations and places have been done. For example, Norman Carrier and A.M. Farrag (1959) presented methods of splitting large age groups into small ones as a basis of correction. Their methods were successfully applied to the Egyptian data. Another method that deals with specific situations was developed by Paul Demeny and Frederic Shorter (1968). The Demeny-Shorter method was evolved to deal with Turkish age distributions which were largely distorted by past wars. Furthermore, Van de Walle's analytical study (1968) of the African age data was a big eye-opener to the possibilities and limitations of using demographic methods to analyse highly defective age data.

More recently, a very interesting study of 'gross' and 'net' age errors was done by Gibril (1975). He matched individual respondents to the 1973 Gambian census by name with the Medical Research Council (MRC) records compiled over a twenty-year period for four villages - Keneba, Mandaur, Kanton Kunda and Jali. Then by fixing the mean ages of the MRC records at 2.5, 7.5, 12.5, etc., he calculated the corresponding mean ages and hence the standard deviations of the census distributions, by sex (see Table 1.1). The results of the calculations displayed in Table 1.1 show that with the exception of one value (i.e. males aged 65-69), all the net errors - the difference between the mean ages of MRC and the Census - were much smaller than the gross errors - the standard deviations. His study also indicates that the gross errors are more important than the net errors in distorting the age structure of human populations because the former errors reflect the variability of the ages allocated by the census around the mean ages. Thus, Gibril's work, though limited in area and in the number of people studied, highlights the need for a detailed study of age errors.

TABLE 1.1. Net and Gross Errors of four Gambian Villages

AGE Group	MALES Net Errors = MRC-Census Mean Ages	Gross Errors (or Standard Deviation)	FEMALES Net Errors = MRC-Census Mean Ages	Gross Errors (or Standard Deviation)
0-4	+0.51	1.83	+0.71	2.01
5-9	+0.22	2.50	+0.11	2.48
10-14	-0.88	3.03	-1.22	3.61
15-19	-0.15	4.23	+0.88	4.31
20-24	+2.15	5.29	+1.54	5.42
25-29	+3.29	5.98	+0.85	4.70
30-34	+0.88	8.15	+0.25	5.37
35-39	+2.38	6.11	-2.00	6.15
40-44	+3.97	6.80	-0.38	7.79
45-49	+1.64	4.38	-0.34	8.55
50-54	+2.85	3.77	+0.31	9.91
55-59	+4.81	8.82	+3.83	8.78
60-64	+5.15	8.73	+5.78	9.77
65-69	+4.93	3.36	+6.71	8.39
70-74	+1.87	6.02	+5.40	5.66

Source: Gibril, M.A.(1975) Table 5.

1.4 Objectives of the study and Summary of the Chapters.

Despite the above-mentioned attempts by various demographers to develop methods of collecting and analysing age data, there is still a great need to find more appropriate and realistic methods for analysing incomplete age data collected at demographic inquiries in developing countries. The present study is, therefore, devoted to applying current and new methods of analysis in order to achieve five objectives:

(i) to examine the feature of age heaping in tropical African inquiries;

(ii) to discern and investigate patterns of age and coverage errors in the tropical African surveys;

(iii) to look at the differences in errors of age data between male and female respondents;

(iv) to contribute to the growing number of methods of detecting, measuring and adjusting for various errors of age data from the developing countries;

(v) to stimulate further research in the field of errors of age data and related demographic characteristics.

In view of the above objectives, the thesis will be divided into seven chapters. Chapter one (foregoing) is a brief review of the subject of age errors in developing countries. The phenomenon of age heaping in tropical Africa will be looked at by the use of thirteen African censuses in Chapter 2. A study of patterns of age and coverage errors in tropical Africa by utilising twenty-five inquiries will follow in Chapter 3. Chapter 4 examines the differences in age and coverage errors between male and female African populations.

Furthermore, methods that utilise age data reported in successive censuses of the same country are presented in chapters 5 and 6. Chapter 5 is divided into two parts: the first one is a critical appraisal of the Demeny-Shorter method, and the second part is a presentation of a method based on the same idea as the Demeny-Shorter method, but takes advantage of age data from three successive censuses. The method presented in Chapter 6 is also based on the Demeny-Shorter idea, but uses per cent age distributions of two successive censuses. This method is initially developed to use age data of quinquennial censuses and then is extended to utilise decennial censuses and single year age distributions. The final Chapter (7) gives a summary of the findings and the main conclusions of the study of age errors in the preceding six chapters.

CHAPTER TWO

AGE HEAPING IN AFRICAN INQUIRIES

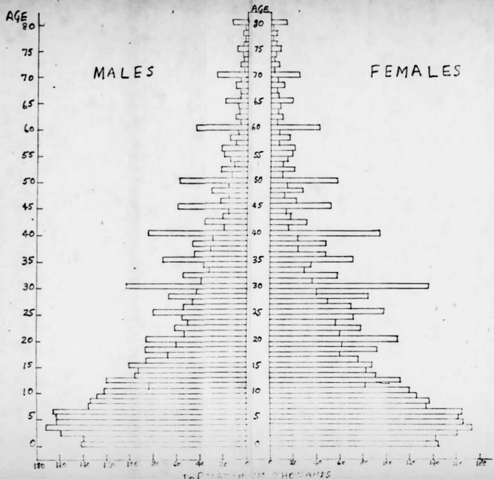
2.1 Introduction

Many studies of patterns of reporting ages in demographic and social surveys in developing countries have noted frequent occurrence of age heaping at certain digits and age avoidance at other digits. This kind of systematic age error is mainly due to the illiteracy of the population enumerated and the almost total lack of socio-economic need for remembering birthdays in many societies in the developing countries.

Typical demographic inquiries showing age digit preference error are the tropical African censuses and national surveys conducted in the last two to three decades. A cursory glance at most age distributions reported in single years from these African surveys will reveal heaping of populations on ages ending in certain digits and avoidance of others. This fact is illustrated by Fig.2.1 which shows the age-sex pyramid of the de facto population of Ghana 1970. It is clear from this example that a saw-toothed pattern of reporting ages in single years is shown after age 20. Populations are concentrated at ages that are multiples of 0 and 5 and the heaping becomes more pronounced with higher ages. It is, thus, interesting to explore this seemingly common characteristic of tropical African age data further and attempt to examine whether there are any variations to the phenomenon.

So far several students of African demography have attempted to identify patterns of age heaping in African surveys. Worthy of note is a study done by Etienne Van de Walle (1968) which indicated age heaping at digits 0 and 5 in the British and Portuguese oriented inquiries and age avoidance of these digits in the French supervised surveys. However,

Figure 2.1: Age-Sex Pyramid of the Defacto Population of Ghana 1970



Van de Walle's work did not measure the extent of age digital preference across tropical Africa. Therefore, it is the intention in the study in this chapter to: (i) use data from the most recent 13 censuses taken in tropical Africa; (ii) measure the extent of age digital preference in these surveys; (iii) discern the patterns of age heaping in the inquiries; (iv) indicate the distorting effect of age heaping on the age structures; and (v) adjust the age structures for the age heaping errors. The basic analytical procedures used in detecting, measuring and correcting for the error of age heaping are: first, the Myers' 'Blended' method and second, the Sprague multipliers.

2.2 Measuring Digital Preference

A standard technique for measuring how much terminal digits are favoured or disfavoured in age reporting was developed by Robert Myers (1940). This method which produced digit preference indices was critically examined by Norman Carrier (1959), who did not find serious objections to it. Norman Carrier (1959) and other writers, such as Roberto Bachi (1951) and K.V. Ramachandran (1965), have proposed more theoretically elegant methods of measuring indices of age heaping. However, the simplicity of the computations of the Myers' method for generating indices of digital preference has, in practice, made it preferable to other methods which, besides being more laborious in computation, scarcely yield different results.

The procedure of the calculations involved in the use of Myers' method will be given in brief. The procedure follows five steps:-

(i) The populations ending in each digit over a 10 to 69 range starting with the lower limits of the range (10,20,30....,60; 11,21,...,61; 12,22,..,62; 19,29,...,69) were summed up. The age range was restricted to ages 10-69 because of the lack of data in single years above age 70 for some of the censuses used; and also in order to avoid extreme and unrepresentative age distortions that occur below age 10 and above age 70.

(ii) A second sum, similar to the one in (i), covering the age range 20-69 is calculated.

(iii) The two sums (in steps (i) and (ii)) are weighted: first sum weights are 1, 2,...,10 and the second sum is weighted by 9,8,.....1,0. A blended population is obtained by adding the two resulting products. If the true change with age was linear the expected values of the numbers for each digit would be the same. The small differences from linearity have little effect.

(iv) The blended population distribution is converted into percentages.

(v) Deviations of each percent from 10.00%, the expected value for each percent, are computed.

Table 2.1 illustrates the computational procedure of the Myers' method in generating indices of age heaping by using female data from the Ghana census of 1970. Column (7) of the table represents the indices of preference for each terminal digit. The terminal digit preferences are added, regardless of the signs, to form an overall index of preference for a population - see the bottom row of Table 2.2.

2.3 The resulting patterns of age heaping

Very interesting patterns of terminal digit preference indices have emerged from the application of the above procedure to 13 censuses by sex taken in tropical Africa between 1960 and 1970. Table 2.2 shows that the 26 different population distributions display ten combinations of the first three preferred digits as follows:- (i) 0,5 and 8, exhibited by 14 populations; (ii) 0,8 and 5 by 3; (iii) 0, 5 and 2 by 1; (iv) 9,7 and 5 by 2; (v) 9,0 and 5 by 1; (vi) 9,1 and 7 by 1; (vii) 5,8 and 0 by 1;

TABLE 2.1: Calculation of Preference Indexes for Terminal Digits by Myers' Blended Method for the Ghana Females, 1970

Terminal digit a	Population with terminal digit a		Blended population				Deviation of Percent from 10.00 (6)-10.00
	Starting at age 10+a ending at age 60+a	Starting at age 20+a ending at age 60+a	weights for Column 1	Column 2	Number (1)X(3)+(2)X(4)	Percent distribution	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	558781	439017	1	9	4509934	19.87	+9.87
1	210917	128931	2	8	1453282	6.40	-3.60
2	309382	196682	3	7	2304920	10.15	+0.15
3	212027	121310	4	6	1575968	6.94	-3.06
4	227990	144951	5	5	1864705	8.22	-1.78
5	347377	259780	6	4	3123382	13.76	+3.76
6	239546	163712	7	3	2167958	9.55	-0.45
7	158583	97995	8	2	1464654	6.45	-3.55
8	277442	185678	9	1	2682656	11.82	+1.82
9	155013	91758	10	0	1550130	6.83	-3.17
Total	-				22697589	99.99	0.00
Overall Index of preference (a)	-						31.21

(a) Sum of the deviations from 10.00% disregarding the sign

(viii) 0,8 and 9 by 1; (ix) 6,8 and 5 by 1; (x) 0,6 and 8 by 1 population distribution. It is significant that the picture in Table 2.2 is, thus, dominated by a pattern of heavy concentration on digits 0 and 5. The preference of digits 0 and 5 in African censuses is largely due to the rounding of ages on the multiples of 0 or 5 by enumerators or the respondents where there are no birth certificates to refer to and where the bulk of the population does not have any incentive to recall the dates of birth. This practice of rounding up ages to 0 or 5 is not restricted to African populations only. Carrier (1959) found the same practice in the Maoris of New Zealand; nor is it confined to the developing societies - Myers (1940) showed its presence in the Whites of the United States.

However, as can be seen from Table 2.2, it is pertinent to note that the African populations of Rhodesia and Zambia, in 1969 censuses, heaped their ages on terminal digit 9 and the population of Lesotho, in the 1966 census, heaped on digit 6 instead of the expected 0 and 5. This avoidance of terminal digits 0 and 5 in age statements is not an uncommon feature of age heaping in censuses. For instance, Van de Kaa (1971) found a peak of age heaping at digit 5 and 6 instead of 0 in the 1966 census of Papua-New Guinea. The cause of this kind of age heaping is mainly the wording of the question on age. There were two main questions on age used in the tropical African censuses, namely 'completed years of age' and 'date of birth'. While respondents will tend to round their ages to 0 in reply to the former question, there is a tendency to round up the year of birth to 0 in response to the latter question. Thus, the use of 'date of birth' in Rhodesian and Zambian censuses of 1969 gave rise to respondents heaping their birth dates on years ending in 0 such as 1900, 1910, 1920 etc. and resulted in age heaping on terminal digit 9.

Furthermore, it is possible that the pattern of age heaping which disfavours numbers that end in 0 and 5 arose from the enumerators

TABLE 2.2. Digital Preference Indices for 13 Censuses, Black African Countries

Terminal Digit	BOTSWANA 1964		GHANA 1960		GHANA 1970		KENYA 1962		KENYA 1969		Lesotho 1966		Liberia 1962	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
0	3.76	4.30	10.00	11.16	7.67	9.87	9.72	12.43	5.37	6.39	0.84	1.96	10.67	13.11
1	-3.19	-2.64	-3.53	-3.51	-3.22	-3.60	-5.10	-4.89	-2.64	-3.05	-3.46	-3.16	-3.46	-3.80
2	-0.67	-0.77	-0.07	0.06	0.09	0.15	0.03	-0.24	0.03	-0.21	0.07	-0.05	0.03	-1.18
3	-2.01	-2.00	-3.52	-3.68	-2.75	-3.06	-3.84	-4.59	-2.30	-2.63	-0.79	-0.34	-4.37	-4.81
4	-0.97	-0.95	-1.98	-2.18	-1.93	-1.78	-1.80	-2.24	-1.60	-1.65	0.08	0.27	-3.70	-4.17
5	1.20	0.78	3.61	2.99	4.28	3.76	5.68	4.10	2.96	2.43	1.25	0.56	3.98	3.73
6	0.01	0.08	-0.43	-0.48	-0.37	-0.45	-0.85	-1.40	-0.86	-0.60	2.22	1.75	-2.14	-2.49
7	-1.51	-1.68	-2.92	-3.48	-2.53	-3.55	-3.33	-4.03	-1.63	-2.00	-0.57	-1.23	-4.05	-4.64
8	2.39	1.91	1.22	1.56	1.35	1.82	2.59	3.33	1.60	2.18	1.63	1.17	3.23	4.05
9	0.99	0.96	-2.38	-2.44	-2.59	-3.17	-3.09	-2.47	-0.94	-0.87	-1.27	-0.93	-0.20	0.18
Overall Index of preference	16.70	16.07	29.66	31.54	26.78	31.21	36.03	39.72	19.93	22.01	12.18	11.42	35.83	42.16

Table 2.2 (continued)

Terminal Digit	NIGERIA 1963		RHODESIAN AFRICANS 1969		SWAZILAND 1966		TANGANYIKA 1967		UGANDA 1969		ZAMBIA 1969	
	M	F	M	F	M	F	M	F	M	F	M	F
0	18.77	20.14	0.93	0.70	1.90	3.62	6.94	10.17	7.73	10.99	1.34	3.01
1	-3.21	-3.42	0.88	1.03	-3.76	-3.02	-4.39	-4.81	-3.13	-3.82	-0.24	0.34
2	-1.59	-2.34	-1.19	-1.42	-0.28	-0.41	-0.43	-0.79	-0.06	-0.62	-1.09	-1.00
3	-4.10	-4.61	-0.87	-0.50	-1.97	-1.75	-2.60	-3.32	-2.66	-3.54	-1.52	-1.07
4	-4.74	-5.00	-1.52	-0.79	-0.64	-1.12	-3.09	-3.31	-2.07	-2.45	-1.52	-1.54
5	7.61	7.11	-0.47	-0.66	2.51	2.12	5.61	4.94	3.86	3.86	1.52	0.74
6	-3.23	-3.46	-2.69	-2.55	0.13	-0.37	-1.70	-2.26	-1.35	-1.76	-2.22	-2.35
7	-3.22	-2.41	1.50	0.82	-1.47	-1.89	-1.63	-2.85	-1.59	-2.70	1.66	0.00
8	-2.36	-1.94	-1.16	-2.40	2.25	2.39	2.77	3.95	0.80	1.96	-0.68	-1.71
9	-3.94	-4.08	4.60	5.75	1.33	0.43	-1.48	-1.72	-1.52	-1.91	2.74	3.59
Overall Index of preference	52.77	54.51	15.81	16.62	16.24	17.12	30.64	38.12	24.77	33.61	14.53	15.35

making deliberate attempts (on the instructions of census officials) to avoid digits 0 and 5 when estimating ages of highly illiterate populations. The avoidance of 0 and 5 was also found in the French organised demographic inquiries in Africa by Van de Walle (1968) who attributed it to the interviewers' attempts to impress their supervisors, who were sceptical of ages rounded to 0 and 5, with seemingly accurately probed returns of single ages.

The final reason for the avoidance of 0 is probably the misuse of historic event calendars in the estimation of single ages, as in the case of Papua-New Guinea (see Van de Kaa, 1971). It is probable that most of the enumerators in the Lesotho census of 1966 found that they had to resort to the use of historic event calendars because respondents were unable to answer the 'completed age' question put to them. Consequently, the enumerators had to estimate the dates of birth of most people, resulting in the rounding up of years of birth to 0. Thus, the peak of age heaping in Lesotho is shown by Table 2.2 to be 5 or 6.

Besides considering the most favoured terminal digits, it is important to examine the ranking of all terminal digits in order of digit preference. Thus, by use of the digit preference indices shown in Table 2.2, Table 2.3 is compiled to indicate the ranking of all ten terminal digits (0 to 9). The overall ranking in the 13 censuses is, from first to tenth, 0, 5, 8, 2, 9, 6, 7, 4, 1 and 3. For reasons discussed above, it is clear from Table 2.3 that terminal digits 0 and 5 are most favoured. It is also noteworthy that next to 0 and 5, digits 8 and 2 are preferred. As can be seen from Table 2.3, out of 26 populations considered, digit 8 ranks 2nd. six times and 3rd. fifteen times; digit 2 ranks 4th. fourteen times and 6th. seven times. The probable reason for the high ranking of 8 and 2, as Carrier and Hobcraft (1971) observed, is that populations tend to

Table 2.3. **Frequencies of each terminal digit per rank**

Terminal Digits \ Rank	1	2	3	4	5	6	7	8	9	10	Total
0	20	1	2	3	0	0	0	0	0	0	26
1	0	1	0	2	2	1	2	0	1	17	26
2	0	0	1	14	1	7	1	2	0	0	26
3	0	0	0	0	1	1	3	4	14	3	26
4	0	0	0	0	2	6	8	6	2	2	26
5	1	15	6	2	1	1	0	0	0	0	26
6	1	1	0	0	14	3	3	0	0	4	26
7	0	2	1	0	2	2	4	10	5	0	26
8	0	6	15	1	0	1	1	0	2	0	26
9	4	0	1	4	3	4	4	5	1	0	26
Total	26	26	26	26	26	26	26	27*	25*	26	--

* Total is not 26 because of 2 terminal digits having the same rank.

favour even numbers rather than odd ones in reply to questions on 'completed years of age'. Also, despite the fact that on arithmetic average basis, odd digit 9 ranks higher than even digits 6 and 4, and 7 precedes 4, an examination of years of birth given will show that years ending in 0 or even numbers were preferred to the odd ones.

Statements that even numbers are attractive and odd numbers are avoided can be shown by leaving out the two censuses of Rhodesia and Zambia where questions were on 'dates of birth'. The resulting ranking order would be 0, 5, 8, 2, 6, 4, 9, 7, 3 and 1, thus making all the even digits precede odd digits (with exception of digit 5 for reasons already mentioned). Hence, it can be seen from Table 2.2 that digit 1 is disliked, mostly because of preference for 0 and, to a lesser extent, in preference for even digit 2; digit 3 loss of age statements is in credit to 2 and 5; 7 is avoided in favour of its even neighbour 8 and also 5; digit 9 is avoided in preference for 0 and 8. However, Table 2.2 also shows that for reasons already mentioned, odd digit 5 gains age statements heavily at the expense of even digits 4 and 6.

Furthermore, Table 2.2 presents different overall indices of preference. An overall index of preference in our present study will be defined as a measure of age heaping for all digits put together. It is obtained by summing up all the absolute deviations from 10.00% (i.e. terminal digits preference indices). The smaller an overall index of preference is, the less digit preference error there is. The theoretical range of the index is 0 when there is no age heaping error at all, and 180 when all ages were reported at a single digit, say 0.

It is clear from Table 2.2 that East and West African countries show higher overall indices of preference, apparently because of the high degree of age heaping on digits 0 and 5 and much disfavour for 4, 3, 1 and 9. On the other hand, the countries of Southern Africa have low overall indices of preference, largely because these populations do not have very heavy heaping on their most favoured digits, namely 9 and 6. The foregoing observations do not necessarily mean that the black populations in the Southern African countries reported their ages better than the Eastern and Western African populations in regard to the age heaping errors. As mentioned above, it is probable that the differences in questions of age and in the survey method used in different areas of Africa were crucial factors in causing disparity of heaping errors.

In addition, Table 2.2 provides a comparison of age heaping errors for two censuses of the same country. The overall index of preference and age heaping error at every terminal digit for the 1969 Kenya census shows an appreciable improvement for both males and females over the 1962 census results. Also, the Ghana results in the 1970 census show some reduction in the overall index of preference and terminal digital indices over the 1960 census. The improvement shown in the Ghana and Kenya censuses was, perhaps, due to the improved methods of age probing that were used in the latter censuses after learning from past experience. However, the analysis shows more heaping on digit 5 in 1970 than in the 1960 census of Ghana, implying more rounding up at 5 in the latter than the former census.

¶ Another pattern of age heaping displayed in Table 2.2 that is worth noting is about sex differentials. Our analysis shows that in all censuses considered, females heaped their ages on 0 whereas males heaped their ages on digit 5. In most cases the overall index of preference is higher for females than for males probably because the enumerators who were predominantly male were likely to get more frank answers from their fellow men than from the women. Another possible reason is the sex differential of literacy in tropical Africa. The percentage of literate population is much higher for males than for females. For instance, the 1969 Ugandan census found that 40% of all males, compared with 21% of all females, claimed to have been to school. The cause of this inequality is the discriminatory attitudes of African men against women emanating from religious beliefs. In Nigeria, for example, the majority of the population is Muslim and they prefer to educate their sons rather than their daughters. They also hold a socio-cultural belief that sons should be educated to continue the lineage of their fathers in comparison to educating daughters who would eventually marry into another clan. The higher education for males possibly led to less ignorance of ages since they were probably in a better position to make a good guess of age than were females.

2.4. Determining the best age grouping method

A step before adjusting the age structure for the age heaping is to determine the best age grouping method for each population distribution by using the information contained in Table 2.2. The deviations from 10.00% corresponding to each of the five digits of the particular grouping method are summed and the sums are shown in Table 2.4. The closer the sum is to zero, the better is the given group. For example, the sums of the deviations of five digits for different age combinations for the Kenyan males of the 1969 census are (see Table 2.4) 1.14, 3.55, 1.77, 3.43, 0.47 for 0-4, 1-5, 2-6, 3-7, 4-8 respectively. The chosen age groupings are only marginally different from the sum of the conventional age combinations, namely 0-4, 5-9 etc. For example, the Kenya male population of the 1962 census is grouped under 2-6, 7-1 etc. combination, whose sum - 0.78 - differs marginally from the sum of 0-4, 5-9 etc. combination - 0.99, and as can be seen later in Table 2.6(a), the effect of the re-grouping of this particular population creates only small differences.

Table 2.4: **Sums (Regardless of sign) of Deviations of Percent from 10.00 For Various Combinations of Five Ages**

Census / Age Groupings	BOTSWANA 1964		GHANA 1960		GHANA 1970		KENYA 1962		KENYA 1969		LESOTHO 1966		LIBERIA 1962	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
0-4, 5-9	3.08	2.06	0.90	1.85	0.14	1.58	0.99	0.47	1.14	1.15	3.26	1.32	0.83	0.85
1-5, 6-0	5.67	5.58	5.49	6.32	3.53	4.53	5.03	7.86	3.55	5.11	2.85	2.72	7.52	10.23
2-6, 7-1	2.44	2.86	2.39	3.29	0.68	1.38	0.78	4.37	1.77	2.66	2.83	2.19	6.20	8.92
3-7, 8-2	3.28	3.77	5.24	6.83	3.30	5.08	4.14	8.16	3.43	4.45	2.19	1.01	10.28	12.38
4-8, 9-3	1.12	0.14	0.50	1.59	0.80	0.20	2.29	0.24	0.47	0.36	4.61	2.52	2.68	3.52

Census / Age Groupings	NIGERIA 1963		RHODESIAN AFRICANS 1969		SWAZILAND 1966		TANGANYIKA 1967		UGANDA 1969		ZAMBIA 1969	
	M	F	M	F	M	F	M	F	M	F	M	F
0-4, 5-9	5.13	4.77	1.77	0.98	4.75	2.68	3.57	2.06	0.19	0.56	3.03	0.26
1-5, 6-0	6.03	8.26	3.17	2.34	4.14	4.18	4.90	7.29	4.06	6.57	2.85	2.53
2-6, 7-1	6.05	8.30	6.74	5.92	0.25	1.53	0.51	4.74	2.28	4.51	4.83	5.22
3-7, 8-2	7.68	8.37	4.05	3.68	1.44	3.01	1.78	6.80	3.81	6.59	2.08	4.22
4-8, 9-3	5.94	5.70	4.34	5.58	2.78	1.13	1.96	0.47	0.35	1.09	1.24	4.86

As a result of the above selection procedure, the suitable age grouping methods for females in the 13 censuses are as follows:-

(i) 0-4 and 5-9 are appropriate for Liberia 1962, Nigeria 1963, Rhodesian Africans 1969, Uganda 1969 and Zambia 1969;

(ii) 3-7 and 8-2 for Lesotho 1966;

(iii) 4-8 and 9-3 for Botswana 1964, Ghana 1960 and 1970, Kenya 1962 and 1969, Swaziland 1966 and Tanganyika 1967.

More combinations emerged for the males:-

(i) 0-4 and 5-9 for Liberia 1962, Nigeria 1963, Rhodesian Africans 1969, Uganda 1969 and Ghana 1970;

(ii) 2-6 and 8-2 for Lesotho 1966;

(iii) 4-8 and 9-3 for Botswana 1964, Ghana 1960, Kenya 1969 and Zambia 1969.

It may be noted that all the censuses, save five, have both males and females in the same grouping, which implies very similar patterns of age heaping on terminal digits. The five exceptions are, Ghana 1970, Kenya 1962, Swaziland 1966, Tanganyika 1967 and Zambia 1969, probably because, as can be shown by Table 2.2, there is a substantial difference in the emphasis of age heaping between the sexes, despite the broad similarity of patterns.

2.5 Adjusting for age heaping errors

The next step in our study of age heaping is an attempt to correct age distributions for errors due to digital preference. To do this we form five-year age distributions of our populations based on the above suitable groupings. 10 out of 26 populations have age groups 0-4 and 5-9 as appropriate combinations and are excluded for a reason to be made clear later. The results are then subjected to an oscillatory interpolation formula in order to split the five year age groups into single years. The formula used is one developed by Thomas Bond Sprague in 1880. This basic formula was later used by Wilson H. Grabill of the U.S. Bureau of the Census to produce what are called the 'Sprague Multipliers'. An advantage of these interpolation coefficients is that they maintain the same totals for each age group.

An electronic computer has been used to generate single year populations from given five year groups using the Sprague multipliers for each sex of the eight censuses. The estimated populations in single years are then summed up according to the conventional five year age grouping, namely 0-4, 5-9, 10-14, etc. The resulting estimated age distributions, numerically and in percentages, are shown in Table 2.5(a) and (b) and 2.6(a) and (b) respectively. Furthermore, ratios of the estimated to the enumerated populations are calculated. The ratios give an indication of the likely effect of digit preference on the age structure and are contained in Table 2.7.

The performance of the procedure in adjusting for age heaping is shown by Tables 2.5(a), 2.5(b), 2.6(a) and 2.6(b). The transfer of population from age groups with surplus numbers to deficient age groups is shown by Tables 2.5(a) and 2.5(b) to be substantial. In addition, a comparison of the estimated and the enumerated percent age distributions by use of a model stable age distribution (which assumes ℓ_2= 802 and GRR = 3.0 and is based on the Brass African Standard, see Carrier and Hobcraft 1971) shows that the estimated structures are closer in pattern and values to the stable than the enumerated distributions. However, it must be noted that the estimated population percent age distributions would have been much less irregular had it not been for other types of distortions not dealt with by the present adjusting

Table 2.5(a) **Enumerated and Estimated Male Populations**

Age Group	BOTSWANA AFRICANS 1964		GHANA 1960		KENYA 1962		KENYA 1969		LESOTHO AFRICANS 1966		SWAZILAND AFRICANS 1966		TANGANYIKA AFRICANS 1967		ZAMBIA AFRICANS 1969	
	Enum.	Estim	Enum.	Estim	Enum.	Estim.	Enum.	Estim.	Enum.	Estim.	Enum.	Estim	Enum.	Estim.	Enum.	Estim.
10-14	33084	34137	357831	352770	529108	549686	714707	712510	61062	61390	24197	24979	642706	674397	234473	236967
15-19	25300	25216	275542	289887	374742	386928	560152	567362	39788	39082	17425	17239	501411	502439	170760	167458
20-24	18155	17889	268336	264732	256423	267415	428105	426432	16451	17700	10463	11775	368478	400256	130603	132918
25-29	17775	17797	278601	287301	261972	258895	349594	348824	14254	13696	12019	10708	447621	438102	122121	116457
30-34	13387	13964	242515	243988	213601	224585	280948	287330	15187	14520	8382	9229	345882	378704	112695	119794
35-39	14428	13252	198231	195232	190835	190918	252136	242539	14049	14871	10206	9430	330751	301542	114264	105157
40-44	10239	11936	165937	169464	156625	155125	193936	205001	13044	14106	5985	7016	212477	225119	85010	94998
45-49	11057	9879	122756	113015	140745	134899	172508	160436	17274	15392	6131	5044	246020	216288	83146	71396
50-54	8320	8722	96775	93912	106764	96766	132466	135286	13430	14523	5530	5531	170481	173517	58110	72922
55-59	6787	6353	59307	61257	71520	82173	114669	114769	10342	10477	3392	3849	105399	124870	62067	51109
60-64	5755	6070	63467	60774	72744	58618	102466	102057	8164	8440	2955	2923	103881	87903	28655	34728
65-69	3945	3678	32377	33013	39185	41968	74611	69320	9586	7599	3431	2966	74223	77813	28047	24071
70-74	2214	2654	29796	28740	37004	32001	48363	52307	3960	4786	905	1445	57317	45653	8483	11413
75-79	1837	1533	16183	15951	20817	19238	31837	27993	2168	2464	681	454	80406	77928	4474	3222

Table 2.5(b) Enumerated and Estimated Female Populations

Age Group	BOTSWANA AFRICANS 1964		GHANA 1960		GHANA 1970		KENYA 1962		KENYA 1969		LESOTHO AFRICANS 1966		SWAZILAND AFRICANS 1966		TANGANYIKA AFRICANS 1967	
	Enum.	Estim	Enum.	Estim.	Enum.	Estim.	Enum.	Estim.	Enum.	Estim.	Enum.	Estim.	Enum.	Estim.	Enum.	Estim.
10-14	31803	32976	323460	306300	488206	493574	459384	446342	663808	667604	60781	60246	24274	24124	579110	608642
15-19	25742	25607	265534	270240	379038	386234	372936	388792	544847	546917	48544	48953	18496	18433	558663	555602
20-24	21960	21394	322576	321388	375545	368159	369736	366360	450096	453563	37237	37428	15405	15573	528179	546245
25-29	20705	21118	306329	316707	341481	365150	351284	358570	411245	409547	31404	32064	15339	15209	556731	551030
30-34	15785	16330	245883	243073	296867	284883	265152	266251	299241	305076	31200	28960	10151	10401	387823	395287
35-39	15818	14585	179182	176987	216855	218659	202726	196825	264819	256347	23711	26280	9726	9095	326533	311867
40-44	11462	13154	145572	146499	175626	174193	159067	162102	201936	210663	20349	21093	6731	7669	226656	238921
45-49	10532	9303	95590	88798	128052	122300	120782	113123	163852	153393	23416	21420	6339	5850	226749	203233
50-54	8131	8532	81715	77884	111777	105356	95388	92809	139072	140896	19409	20176	5308	5300	176154	184438
55-59	6501	6165	48412	50893	66043	70277	55116	56508	102235	101554	13480	13787	3311	3112	100450	98775
60-64	5580	5947	54572	52574	71076	67497	62505	61332	94508	94518	12061	11871	3272	3384	111818	111864
65-69	4227	3803	28581	32416	46491	46024	32360	30937	63307	58933	15877	12365	3965	3685	72161	66331
70-74	2680	3225	26733	25560	40388	39222	29513	28890	45987	49194	8072	9625	1721	2165	60727	66081
75-79	2368	1997	14778	14692	20581	20924	13907	12391	27481	23833	3894	4831	1246	1084	64588	59705

Table 2.6(a): Percent Age Distributions of Enumerated and Estimated Male Population

Age Group	BOTSWANA AFRICANS 1964		GHANA 1960		KENYA 1962		KENYA 1969		LESOTHO AFRICANS 1966		SWAZILAND AFRICANS 1966		TANGANYIKA AFRICANS 1967		ZAMBIA AFRICANS 1969		MODEL STABLE DISTRIBUTION
	Enum	Estim	Enum	Estim	Enum	Estim	Enum	Estim	Enum	Estim	Enum	Estim	Enum	Estim	Enum	Estim	
10-14	12.89	13.30	10.52	10.37	13.92	14.46	13.04	13.00	16.70	16.79	14.08	14.53	11.02	11.56	12.12	12.25	11.95
15-19	9.86	9.82	8.10	8.53	9.86	10.18	10.22	10.35	10.88	10.69	10.14	10.03	8.59	8.61	8.82	8.65	10.40
20-24	7.07	6.97	7.89	7.79	6.74	7.03	7.81	7.78	4.50	4.84	6.09	6.85	6.32	6.86	6.75	6.87	8.72
25-29	6.92	6.93	8.19	8.45	6.89	6.81	6.38	6.36	3.90	3.74	6.99	6.23	7.67	7.51	6.31	6.02	7.60
30-34	5.22	5.44	7.13	7.18	5.62	5.91	5.12	5.24	4.15	3.97	4.88	5.37	5.93	6.49	5.82	6.19	6.46
35-39	5.62	5.16	5.83	5.74	5.02	5.02	4.60	4.42	3.84	4.07	5.94	5.49	5.67	3.86	5.90	5.43	5.47
40-44	3.99	4.65	4.88	4.98	4.12	4.08	3.54	3.74	3.57	3.86	3.48	4.08	3.64	3.71	4.39	4.91	4.59
45-49	4.31	3.85	3.61	3.32	3.70	3.55	3.15	2.93	4.72	4.21	3.57	2.93	4.22	2.97	4.30	3.69	3.80
50-54	3.24	3.40	2.85	2.76	2.81	2.54	2.42	2.47	3.67	3.97	3.22	3.22	2.92	2.14	3.00	3.77	3.07
55-59	2.64	2.48	1.74	1.80	1.88	2.16	2.09	2.09	2.83	2.86	1.97	2.24	1.81	1.51	3.21	2.64	2.40
60-64	2.24	2.36	1.87	1.79	1.91	1.54	1.87	1.86	2.23	2.31	1.72	1.70	1.78	1.33	1.48	1.79	1.78
65-69	1.54	1.43	0.95	0.97	1.03	1.10	1.36	1.26	2.62	2.08	2.00	1.73	1.27	0.78	1.45	1.24	1.28
70-74	0.84	1.03	0.88	0.85	0.97	0.84	0.88	0.95	1.08	1.31	0.53	0.84	0.98	1.34	0.44	0.59	0.75
75-79	0.72	0.60	0.48	0.47	0.55	0.51	0.58	0.51	0.59	0.67	0.40	0.26	1.38	1.11	0.23	0.17	0.39

TABLE 2.6(b): Percent Age Distribution of Enumerated and Estimated Female Populations

Age Group	BOTSWANA 1964		GHANA 1960		GHANA 1970		KENYA 1962		KENYA 1969		LESOTHO 1966		SWAZILAND 1966		TANGANYIKA 1967		MODEL STABLE DISTRIBUTION
	Enum	Estim	Enum	Estim	Enum	Estim	Enum	Estim	Enum	Estim	Enum	Estim	Enum	Estim	Enum	Estim	
10-14	11.75	12.15	9.72	9.21	11.32	11.45	11.69	11.36	12.16	12.23	12.63	12.52	12.80	12.72	9.48	9.96	11.95
15-19	9.51	9.43	7.98	8.12	8.79	8.96	9.49	9.89	9.98	10.02	10.09	10.17	9.75	9.72	9.14	9.09	10.40
20-24	8.11	7.88	9.70	9.66	8.71	8.54	9.41	9.32	8.24	8.31	7.74	7.78	8.12	8.21	8.64	8.94	8.92
25-29	7.65	7.78	9.21	9.52	7.92	8.47	8.94	9.12	7.53	7.50	6.52	6.66	8.09	8.02	9.11	9.02	7.60
30-34	5.83	6.01	7.39	7.31	6.88	6.61	6.75	6.78	5.48	5.59	6.48	6.02	5.35	5.48	6.35	6.47	6.46
35-39	5.84	5.37	5.39	5.32	5.03	5.07	5.16	5.01	4.85	4.69	4.93	5.46	5.13	4.80	5.34	5.10	5.47
40-44	4.23	4.85	4.38	4.40	4.07	4.04	4.05	4.13	3.70	3.86	4.23	4.38	3.55	4.04	3.71	3.91	4.59
45-49	3.89	3.43	2.87	2.67	2.97	2.84	3.07	2.88	3.00	2.81	4.86	4.45	3.34	3.08	3.71	3.33	3.80
50-54	3.00	3.14	2.46	2.34	2.59	2.44	2.43	2.36	2.55	2.58	4.03	4.19	2.80	2.79	2.88	3.02	3.07
55-59	2.40	2.27	1.46	1.53	1.53	1.63	1.40	1.44	1.87	1.86	2.80	2.86	1.75	1.64	1.64	1.62	2.40
60-64	2.01	2.19	1.64	1.58	1.65	1.57	1.59	1.56	1.73	1.73	2.51	2.47	1.72	1.78	1.83	1.83	1.78
65-69	1.56	1.40	0.86	0.97	1.08	1.07	0.82	0.79	1.16	1.08	3.30	2.57	2.09	1.94	1.18	1.09	1.28
70-74	0.99	1.19	0.80	0.77	0.94	0.91	0.75	0.74	0.84	0.90	1.68	2.00	0.91	1.14	0.99	1.08	0.75
75-79	0.88	0.74	0.44	0.44	0.48	0.49	0.35	0.32	0.50	0.44	0.81	1.00	0.66	0.57	1.06	0.98	0.39

procedures.

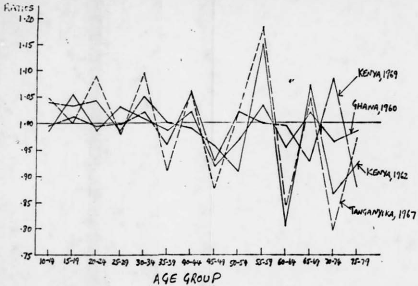
Perhaps a more useful table to examine for our analysis is one that shows ratios, namely Table 2.7, portrayed by graphs in Figures 2.2, 2.3, 2.4 and 2.5. It is important to note that these ratios give an indication of the impact of age heaping on the age structure and hence may be used as adjusting factors for the error present in each age group caused by age heaping. The adjusting factors for the populations of Ghana, Kenya and Tanganyika which have an age heaping pattern of 0, 5, 8 and 2 (see also Table 2.2) do show only small transfers across the borders of age groups. The reason for this observation is largely that in the enumerated populations the effect of age heaping on digits 0 and 2 (in age groups 10-14, 20-24,.....70-74) is almost equally matched by the effect of heaping on digits 5 and 8 (in age groups 15-19, 25-29,....75-79). Also, as observed earlier, it would have meant marginal differences if these populations were not regrouped from the conventional combinations.

Other countries whose ratios are shown in Table 2.7 and Figs. 2.2 to 2.5, exhibit a different pattern of adjusting factors. It is significant that an unbalanced arrangement of age heaping is evident in the ratios, especially in the case of Botswana and Zambia where the order of terminal digit preference is 0, 8, 5 and 9; and 9, 7, 5 and 0, respectively. In both of these populations, the age heaping on digits 9, 7 and 5 for Zambia and 8, 5 and 9 for Botswana which outweighs the heaping on 0, favours age groups 15-19, 25-29,.....75-59, at the expense of 10-14, 20-24,.....70-74. Hence, the ratios for age groups 10-14, 20-24.... 70-74 are almost all above unity meaning adjustment for under-statements of ages,and for 15-19, 25-29.....75-79 are mostly less than unity, indicating correction for over-statements. In addition, the ratios of these populations show larger deviations from unity in advanced ages, thus

Table 2.7: Ratios of Estimated to Enumerated Populations

Age Group	BOTSWANA AFRICANS 1964		GHANA 1960		GHANA 1970	KENYA 1962		KENYA 1969		LESOTHO AFRICANS 1966		SWAZILAND AFRICANS 1966		TANGANYIKA AFRICANS 1967		ZAMBIA 1969
	M	F	M	F	F	M	F	M	F	M	F	M	F	M	F	M
10-14	1.032	1.037	0.986	0.947	1.011	1.039	0.972	0.997	1.006	1.005	0.991	1.032	0.994	1.049	1.051	1.011
15-19	0.997	0.995	1.052	1.018	1.019	1.033	1.043	1.013	1.004	0.982	1.008	0.989	0.997	1.002	0.995	0.981
20-24	0.985	0.974	0.987	0.996	0.980	1.043	0.991	0.996	1.008	1.076	1.005	1.125	1.011	1.086	1.034	1.018
25-29	1.001	1.020	1.031	1.034	1.069	0.988	1.021	0.998	0.996	0.961	1.021	0.891	0.992	0.979	0.990	0.954
30-34	1.043	1.035	1.006	0.989	0.960	1.051	1.004	1.023	1.019	0.956	0.928	1.101	1.025	1.095	1.019	1.063
35-39	0.918	0.922	0.985	0.988	1.008	1.00	0.971	0.962	0.968	1.059	1.108	0.924	0.935	0.912	0.955	0.920
40-44	1.166	1.148	1.021	1.006	0.992	0.990	1.019	1.057	1.043	1.081	1.037	1.172	1.139	1.059	1.054	1.117
45-49	0.893	0.883	0.921	0.929	0.955	0.958	0.937	0.930	0.936	0.891	0.915	0.823	0.923	0.879	0.896	0.859
50-54	1.048	1.049	0.970	0.953	0.943	0.906	0.973	1.021	1.013	1.081	1.040	1.000	0.998	1.018	1.047	1.255
55-59	0.936	0.948	1.033	1.051	1.064	1.149	1.025	1.001	0.993	1.013	1.023	1.135	0.940	1.185	0.983	0.823
60-64	1.055	1.066	0.958	0.963	0.950	0.806	0.981	0.996	1.000	1.034	0.984	0.989	1.034	0.846	1.000	1.212
65-69	0.932	0.900	1.020	1.134	0.990	1.071	0.956	0.929	0.931	0.793	0.779	0.864	0.929	1.048	0.919	0.858
70-74	1.199	1.203	0.965	0.956	0.971	0.865	0.979	1.082	1.070	1.209	1.192	1.597	1.258	0.797	1.088	1.345
75-79	0.835	0.843	0.986	0.994	1.017	0.924	0.891	0.879	0.867	1.137	1.241	0.667	0.870	0.969	0.924	0.720

Figure 2.2: Ratios of the Estimated to Enumerated male populations



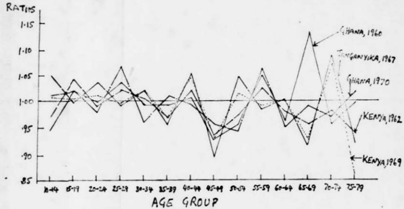


Figure 2.3: Ratios of the Estimated to Enumerated female populations

Figure 2.4: Ratios of the Estimated to Enumerated male populations

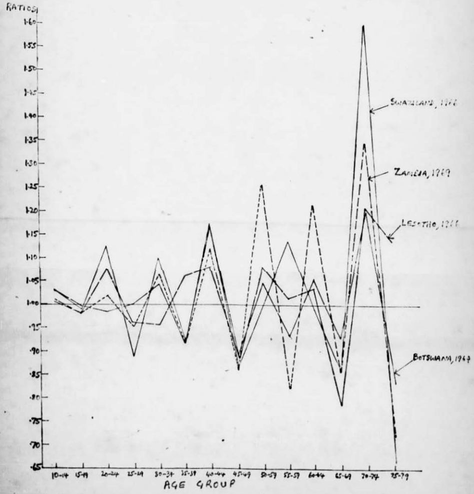
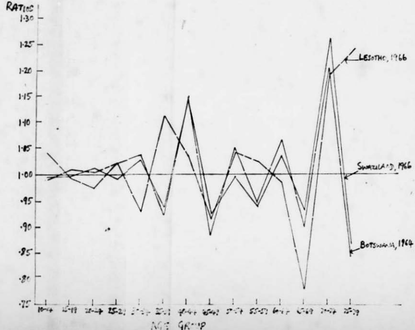


Figure 2.5: Ratios of the Estimated to Enumerated female populations



reflecting bigger age heaping errors in older ages owing to larger memory lapse problems with older people and worse estimation of ages by enumerators.

2.6 Conclusion

The analysis done in this Chapter is quite revealing. For instance, the patterns of age heaping yielded by the Myers' method throw more light on the nature of the age misstatements in African censuses and surveys. The patterns of age heaping discerned by the study of 13 recent censuses in tropical Africa are:-

(i) where completed ages were asked for, the preference was for 0, then 5 followed by even digits 8, 2, 6 and 4 and lastly odd digits 9, 7, 3 and 1;

(ii) where 'dates of birth' question was used ages ending in 9 or 6 were heaped on, but in fact digit 0 and even digits were heaped on as years of birth. This is convincing evidence to suggest that heaping of ages on years of birth is on (a) the multiples of 10, (b) multiples of 5, (c) even digits and (d) odd digits, (given in order of preference). In addition, the correction for age heaping is easy and seems worthwhile.

Nevertheless, one must treat the results outlined in this chapter, particularly in the section on correction for age heaping, with great caution because the basic analytical procedures used have some shortcomings. Firstly, it is not possible to devise standard rules of age grouping, because the variation of digit preference with age may make the best grouping for early and late ages vary. Secondly, the Sprague formula is inadequate: (a) if any particular five year age group is seriously distorted by the coverage error, (b) for the youngest age groups, namely 0-4 and 5-9, and

(c) because the formula makes the assumption that age distribution is a linear function of age, which does not take account of the variations in true age distributions that are very often caused by the occurrence of different cohorts, past human catastrophies and appreciable migration. The study took account of (b) by leaving out the two youngest age groups (0-4 and 5-9). Finally, the digit corrections for age groups are either fairly small or saw-toothed. However, previous studies (e.g. Van de Walle, 1968) have revealed evidence of age pattern distortions in the same direction over several age groups. Since correction for digit preference can not allow for this, a study of other age errors is reported in the following chapters.

CHAPTER 3

PATTERNS OF AGE AND COVERAGE ERRORS IN TROPICAL AFRICAN SURVEYS

3.1 Introduction

There are three chief causes of distortions in an age structure. First, the irregularities that are due to real fluctuations arising from variations in birth cohorts, changes in mortality and appreciable migrations over time. Second, the errors and biases that are created by age mis-statements of respondents and the organisation of censuses and surveys. Third, errors in age data that are caused by incompleteness of a census or survey coverage.

Many attempts at examining, isolating, measuring and adjusting for the irregularities in age data, in regard to tropical African demographic inquiries have been made by various scientists, notably Etienne Van de Walle (1968) and John Grauman (1973). Van de Walle noted that some censuses and surveys of tropical Africa held on different dates and in places distant from one another exhibited similar patterns of errors. Grauman tried to isolate age errors from the real fluctuations. Though meeting limited success in his objective, Grauman introduced a useful idea (originally used by Harro Bernadelli on Burma's data in 1941) of averaging age distributions as a method of isolating the distortion in age structure due to real fluctuations,from that due to age and coverage errors.

In this chapter, the approach which uses 'averages of African age distributions' is developed further with an objective to (i) distinguish the effect of age and coverage errors from the real fluctuations; (ii) discern different patterns of age errors and omissions, and (iii) indicate the extent of these errors in African age data. We shall describe the procedure of our analysis, give the results and discuss them.

3.2 The Procedure

3.2.1. Assumptions and Summary of the Steps

Two main assumptions are made. First, it is assumed that age data from different censuses and surveys taken at different times in different parts of tropical Africa are characterised by dissimilar patterns of real fluctuations which cancel out when the average of all censuses' and surveys' age distributions is taken. The second assumption is that age and coverage errors are similar in these different censuses and surveys in tropical Africa.

Using the two assumptions, we try and investigate how far the different populations deviated in their overall average in the belief that the averaging process removes most of the systematic error. Then the individual populations should show only erratic residuals; but apparently, the residuals for 43 of the 50 populations used show patterns. It appears clear that distinct patterns of the residuals in four groups are shown by 25 populations. The remaining 18 populations show indications of the same patterns, but not so clearly. To distinguish as effectively as possible the nature of the patterns it seems best to work only with the more distinct cases. It should be noted that the real fluctuations confuse the detection of the error patterns of the individual populations when the deviations from the overall average are examined.

When the four groups had been established, the group deviations from the overall average age distribution for all the 25 populations were measured. In order to put these patterns on a comparable basis, a standardized age distribution is used to express the error patterns in the different groups. Finally, the other 18 populations are incorporated to the extent that seems reasonable into the group pattern system.

3.2.2 Steps of Procedure in detail

Our analysis procedure takes the following steps:

a) We take 50 demographic and social inquiries of tropical African countries between 1950 and 1973 (see Appendix Table 3.1 for the reported age distributions from these inquiries) and calculate an average age percent distribution of the reported female populations to be called 'overall average'. The female data are used because they are less influenced by migration than the males. The calculated 'average percent distribution' is shown in Table 3.1. This distribution should incorporate age and coverage errors common to all the populations, but not the individual effects.

b) We then use this overall average distribution as a 'standard' in order to fit estimated curves on logit scale to individual age distributions. The basic estimating equation to be used (see Brass, 1968) is:

$$\bar{Y}(x) = \alpha + \beta\, Ys(x) \qquad ....3.1$$

where $\bar{Y}(x)$ is the logit of the estimated proportions under age x, $Ys(x)$ is the logit of the standard proportion under age x, and α and β are constants. The curves thus constructed will adjust for fertility and mortality differences among populations, but retain the common error elements. The constants α and β are obtained by fitting a straight line. A systematic and arithmetic method known as the 'group average' (see Brass, 1971) is used to fit the straight line. The two equations of the fitting method are:-

$$Y(x) = n\alpha + \beta\Sigma_1\, Ys(x) \qquad ....3.2$$

$$Y(x) = n\alpha + \beta\Sigma_2\, Ys(x) \qquad ....3.3$$

where n is the number of the observations in each group and Σ_1 and

Table 3.1 Averages of the reported male and female age percent distributions of 50 tropical African surveys and censuses

Age Group	Reported Overall Averages Males	Females	Stable Population Distribution ℓ_2=802; GRR=3.0
0-4	17.31	17.01	17.15
5-9	15.38	14.36	13.86
10-14	11.22	9.72	11.95
15-19	8.39	8.59	10.40
20-24	7.38	9.00	8.92
25-29	7.70	8.92	7.60
30-34	6.48	7.27	6.46
35-39	6.12	6.22	5.47
40-44	4.87	4.82	4.59
45-49	4.31	3.88	3.80
50-54	3.22	2.99	3.07
54-59	2.34	2.08	2.40
60-64	1.88	1.84	1.78
65-69	1.35	1.31	1.22
70+	2.05	1.99	1.35
TOTAL	100.00	100.00	100.02

Σ_2 denote summation over group 1 and group 2, respectively. Y(x) is the **logit** of the reported proportion of population under age x . In the present study, group 1 covers population under 5 to under 30 and group 2 ranges from under 35 to under 60 years. The age distributions have been truncated at age 60 in order to minimize the effect of errors that occur in reporting ages at very advanced ages. Solving for α and β will give the required straight line.

c) The fitted curves - $\bar{Y}(x)$ - are subtracted from the reported curves - Y(x) - in order to obtain 'logit deviations' for individual distribution, D(x), ie. $D(x) = Y(x)-\bar{Y}(x)$.

d) The logit deviations for individual censuses and surveys, D(x), are graphed against the logit standard, Ys(x). If age and coverage errors have roughly the same effects in all the populations, D(x) should show no systematic patterns. In fact, this is not the case. An inspection of 50 graphs (one for each inquiry) is done and at least four patterns of the deviations are discernible.

e) In order to examine the four patterns of logit deviations more closely, we select 25 out of the 50 distributions originally considered and put them into four groups by using two criteria: (i) that the logit deviation, D(x), obtained in (c) are similar for the populations in each group; and (ii) that by taking an 'average' age distribution for the populations in a group and using it as a standard for individual group number distributions by use of equations 3.1, 3.2 and 3.3 in step (b) for fitting the estimated curves and step (c) for calculating the logit deviations; the logit deviations so obtained are small on average over the age range. Although we must allow for the part of the logit deviations due to real fluctuations and for the approximate nature of our assumptions, in general the smaller the absolute

TABLE 3.2: **Averages of Absolute Deviations for Each Survey Group by Sex**

Survey Group	1		2		3		4	
Under Age	F	M	F	M	F	M	F	M
5	.012	.035	.025	.027	.024	.048	.010	.058
10	.011	.012	.024	.020	.017	.021	.007	.015
15	.014	.013	.005	.019	.007	.017	.008	.028
20	.009	.013	.015	.010	.015	.028	.005	.037
25	.012	.009	.021	.017	.017	.023	.007	.016
30	.020	.011	.022	.026	.009	.010	.007	.023
35	.018	.014	.017	.029	.010	.013	.009	.025
40	.015	.015	.010	.021	.005	.010	.008	.016
45	.013	.012	.003	.012	.007	.012	.014	.016
50	.011	.012	.007	.010	.004	.003	.009	.010
55	.015	.010	.011	.023	.003	.013	.012	.018
60	.024	.029	.010	.028	.011	.021	.018	.028
65	--	--	.013	.051	.024	.031	.028	.038

logit deviations (in relation to the standard, ie. the group average), the more clustered is the group. Table 3.2 shows the average absolute logit deviations for each group. The deviations are very small, especially in the middle age groups. The resulting 'group averages' by sex are shown in Table 3.3.

f) A 'conditional overall average percentage distribution' of the 25 censuses and surveys selected in (e) is calculated and shown in Table 3.3.

g) Using the equations 3.1, 3.2 and 3.3 in step (b) for fitting estimated curves and step (c) for computing logit deviations, we use the 'conditional overall average' distribution as a standard for each of the 'group average distributions' in order to derive 'group logit deviations'. The group logit deviations, $D_G(x)$, are shown in Table 3.4 and plotted on a graph in Fig. 3.1. These group logit deviations represent the errors which have common features of difference from the overall ones, reducing the real fluctuations in individual populations.

h) Next, we calculate 'overall logit deviations'. To do this we first select a standard age distribution from stable populations whose patterns and levels of mortality and fertility resemble those of African populations. We can select the standard from the existing systems of stable populations, the two best known being: Carrier and Hobcraft (1971) and Coale-Demeny (1966) stable models.

The Coale-Demeny stable population models are based on four life-table families, each representing a single region of mainly European populations (East, North, South and West). This system has been used extensively in the analysis of incomplete age data from developing countries, but it has the disadvantage of being based on an inflexible one-parameter life-table model and may not be suitable for African data owing to the lack of representation of African population in the system. We prefer to use

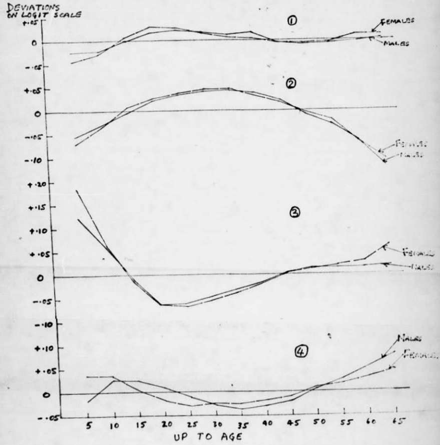
TABLE 3.3: Average age distributions of each group of surveys and the conditional Overall average by sex.

Age Group \ Survey Group	1 F	1 M	2 F	2 M	3 F	3 M	4 F	4 M	Conditional Overall Averages F	Conditional Overall Averages M
0-4	17.87	18.20	16.46	17.60	15.99	17.23	16.97	16.28	17.07	17.50
5-9	14.84	16.38	13.42	15.21	15.28	16.92	13.80	13.61	14.47	15.70
10-14	8.43	10.55	7.87	9.86	12.38	14.07	10.60	11.06	9.57	11.22
15-19	7.34	7.59	7.34	7.15	9.92	10.20	8.87	9.16	8.18	8.34
20-24	9.12	7.24	8.67	6.78	8.08	6.45	8.90	8.44	8.72	7.23
25-29	9.81	7.88	9.17	7.59	7.27	6.00	8.24	8.62	8.88	7.59
30-34	7.66	6.51	7.86	6.55	5.70	4.86	6.83	6.73	7.16	6.23
35-39	6.53	6.32	7.72	6.85	5.13	4.87	5.87	5.88	6.37	6.05
40-44	4.96	4.86	5.72	5.62	3.94	3.69	4.56	4.55	4.84	4.71
45-49	3.81	4.23	4.86	5.34	3.80	3.91	3.55	3.96	3.98	4.33
50-54	2.74	2.93	3.32	3.56	3.04	3.12	3.02	3.04	2.98	3.12
55-59	1.83	2.19	2.63	2.76	2.24	2.39	2.16	2.26	2.14	2.36
60-64	1.83	1.77	2.03	2.11	2.00	2.01	2.10	2.06	1.97	1.95
65-69	1.24	1.33	1.39	1.39	1.98	1.85	1.51	1.47	1.42	1.48
70+	1.98	2.02	1.54	1.62	3.24	2.43	3.03	2.91	2.25	2.18
TOTAL	99.99	100.00	100.00	99.99	99.99	100.00	100.01	100.03	100.00	99.99

TABLE 3.4: Four Patterns of Group Logit Deviations, $D_G(x)$

Survey Group	1		2		3		4	
Under Age	F	M	F	M	F	M	F	M
5	-.046	-.026	-.070	-.054	.134	.122	.036	-.017
10	-.029	-.024	-.036	-.035	.064	.061	.034	.024
15	.005	-.002	.004	-.005	-.013	-.012	.002	.024
20	.028	.016	.025	.020	-.062	-.062	-.018	.009
25	.027	.019	.034	.033	-.068	-.062	-.030	-.011
30	.015	.016	.043	.041	-.056	-.047	-.025	-.028
35	.006	.011	.045	.044	-.040	-.032	-.025	-.037
40	.002	.015	.030	.038	-.020	-.017	-.018	-.029
45	-.007	-.005	.018	.023	.003	.005	-.011	-.019
50	-.008	-.009	-.006	-.008	.012	.016	.009	.006
55	-.004	-.007	-.020	-.029	.018	.014	.016	.025
60	.011	-.005	-.067	-.068	.027	.014	.029	.053
65	.011	.002	-.106	-.118	.060	.018	.043	.077

Figure 3.1: Patterns of Group Logit Deviations, $D_G(x)$



the Carrier-Hobcraft stable models because they are based on the more flexible Brass one-parameter model life tables which approximate the African mortality experience. The stable age distribution (see Table 3.1) chosen from the Carrier-Hobcraft tables is from level 40 and corresponds to ℓ_2 = 802 and G.R.R.=3.0.

As can be seen from Fig. 3.2, which shows logit differences (defined as the difference between the logits of the reported and the standard distributions), the stable population distribution is close to the overall average distribution of 50 female and male populations. It would have been possible by the use of stable populations based on two-parameter model life tables to fit the 'conditional overall average' even more closely. However, an exact fit to the level and shape of stable population is not required, but only a standard of the right order. It should be noted that the averages depend arbitrarily on which populations are selected. Slightly different choices from the original 50 populations for inclusion in the 25 which were to specify the patterns would have resulted in a different average.

By using the selected stable population as standard for 'conditional overall average distribution' (ie. the arithmetic average of the four group average distributions), we fit estimated logit curves by use of equations 3.1, 3.2 and 3.3 and hence calculate the logit deviations, As in step (c). The calculated logit deviations are to be called 'overall logit deviations' denoted as $D_o(x)$, and are shown in Table 3.5 and Fig. 3.3. These overall logit deviations are taken to represent average error patterns with minimal element of real fluctuations of individual populations because most of the latter are assumed to cancel out in the averaging process. It would be expected that the real fluctuations of the 'conditional overall average distribution' would be smoothed to a greater extent than the real fluctuations of the 'group average

Figure 3.2: Logit Differences between Overall Average and Stable Population

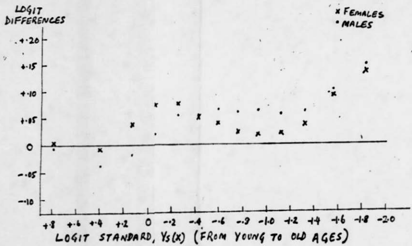
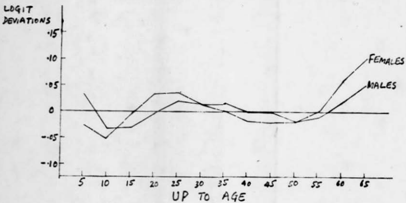


TABLE 3.5: Overall Logit Deviations, $D_o(x)$

Up to Age	Males	Females
5	.033	-.026
10	-.033	-.050
15	-.030	-.006
20	-.003	.033
25	.020	.036
30	.013	.013
35	.016	.001
40	-.001	-.019
45	-.002	-.021
50	-.019	-.020
55	-.011	.001
60	.017	.057
65	.049	.100

Figure 3.3: Overall Logit Deviations, $D_o(x)$



distributions' since the former are related to a fixed underlying age structure, ie. of stable population, while the latter are related to an unknown underlying age structure, ie. of the conditional overall average distribution; and also the former undergo an averaging process over a larger number of populations.

i) To arrive at 'total logit deviations', to be denoted as $D_T(x)$, for each group, we add the overall to the group logit deviations, that is, in algebraic notations, $D_T(x) = D_o(x)+D_G(x)$. The total logit deviations for females can be seen in table 3.6 and Fig.3.5.

j) Because the graph in Fig. 3.2 shows logit differences for males and females which are very close in pattern and size, the same stable population was used as a standard for both males and females.

k) We use the already selected 25 surveys in the same four groups for female as for male populations. The steps in (g), (h) and (i) are repeated for males. The results - 'group','overall' and 'total' logit deviations - are shown in Tables 3.4, 3.5 and 3.6 respectively.

l) In order to arrive at estimates of the extent of age and coverage errors, we convert the 'total' logit deviations calculated in (i) and (j) into natural terms as follows:-

(i) take the already chosen model stable population, namely, consistent with ℓ_2=802 and G.R.R.= 3.0, from the Carrier-Hobcraft two-parameter tables;

(ii) add the 'total logit deviations', $D_T(x)$, of each group of inquiries computed in (i) and (k) to the logits of the model distribution;

(iii) convert the result of (ii) back to natural numbers and obtain the 'modified' age distribution of each group of surveys. The 'modified' age distribution of each group are shown in Appendix, Table 3.2;

TABLE 3.6: The Four Patterns of the Total Logit Deviations, $D_T(x)$

Up to Age	GROUP 1 M	GROUP 1 F	GROUP 2 M	GROUP 2 F
5	+.007	-.067	-.021	-.097
10	-.056	-.080	-.068	-.086
15	-.033	-.001	-.036	-.002
20	+.013	+.061	+.017	+.058
25	+.039	+.064	+.053	+.071
30	+.030	+.027	+.054	+.056
35	+.027	+.008	+.060	+.046
40	+.014	-.017	+.037	+.011
45	-.007	-.028	+.021	-.003
50	-.028	-.028	-.027	-.026
55	-.018	-.003	-.040	-.018
60	+.013	+.068	-.051	-.010
65	+.051	+.110	-.069	-.006

Up to Age	GROUP 3 M	GROUP 3 F	GROUP 4 M	GROUP 4 F
5	+.155	+.107	+.015	+.010
10	+.028	+.014	-.008	-.016
15	-.042	-.019	-.007	-.003
20	-.065	-.029	+.006	+.015
25	-.042	-.031	+.009	+.007
30	-.034	-.043	-.015	-.012
35	-.016	-.039	-.021	-.024
40	-.017	-.039	-.029	-.036
45	+.004	-.018	-.021	-.032
50	-.004	-.008	-.013	-.011
55	+.002	+.019	+.014	+.018
60	+.031	+.084	+.071	+.086
65	+.067	+.159	+.125	+.143

(iv) calculate ratios of the 'modified' to the stable percentage distribution. These ratios (shown in Table 3.9 and Fig.3.6) give an indication of the extent of age and coverage errors.

3.3 Grouping distributions of the remaining 25 censuses and surveys.

As seen above (sect. 3.2.2(e)) only 25 out of 50 populations have been classified into four error patterns. Although the other 25 populations are not closely clustered, with one of the above group average distributions, most of them display fairly similar patterns of errors to those in the four groups. To find out how to classify these populations into the four groups we use two bases:

(i) We fit a stable population distribution as a standard for individual distributions using equations 3.1, 3.2 and 3.3. For the same reasons as already noted, we use the stable distribution in the last column of Table 3.1. It will be seen that the patterns of the logit deviations of 18 out of the 25 populations are similar to those in the four groups defined above. As already noted, the similarity of patterns of logit deviations indicates similarity in the patterns of errors. This similarity between the patterns of 'individual' logit deviations and the 'total' logit deviations, $D_T(x)$, in each survey group is displayed in the Appendix Tables 3.3(a) to (d). Also shown are the seven surveys unclassifiable with the four groups in Appendix Table 3.4.

(ii) Then, we take the averages of the populations displaying patterns of logit deviations similar to those exhibited by the total logit deviations (see Appendix Tables 3.3(a) to 3.3(d)). The stable population distribution in Table 3.1 is used as a standard to fit these averages of the female populations by the logit method using equations 3.1, 3.2 and 3.3, The resulting logit deviations (the logit average minus the logit fitted distributions) are denoted as $D_A(x)$ and shown in Table 3.7. The $D_A(x)$ are compared with the total logit deviations, $D_T(x)$, (see Sect.3.2.2.(i)) for each group by plotting them against the logit standard (see second column Table 3.7) on graphs in Fig.3.4. It will be seen from Table 3.7 and Fig. 3.4 that the shapes of the curves of $D_A(x)$ and the corresponding total logit deviations, $D_T(x)$, are broadly similar. The points of $D_A(x)$ and $D_T(x)$ in the graphs are close in the middle but they tend to diverge in the old and very young ages, implying that the former deviations are less distinctly of the same pattern in every age group as the latter deviations.

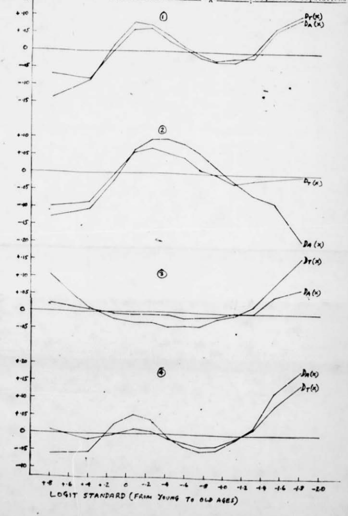
Some of the discrepancy may be real, but there is clearly scope for some individual variation in error even within the same general framework.

On the criteria discussed above, the 18 populations are classified as: 5 in group 1, 4 in group 2, 2 in group 3 and 7 in group 4 - see Appendix Tables 3.3(a) to 3.3(d). Therefore, of the 50 populations originally considered, 43 are classified in the 4 groups as follows:-
Group 1. 15 populations, namely Angola 1950 and 1960, Dahomey 1961, Ethiopia 1965, Ghana 1960, Guinea 1955, Guinea Bissau 1950, Ivory Coast 1957-8 (first survey), Mozambique 1950 and 1960, Senegal 1960-61, Spanish Sahara 1967, Togo 1958-60, Zaire 1955-57, and Zambia 1969;
Group 2. 9 populations, namely Chad 1963-64, West Cameroon 1964-65, Central African Republic 1957-60, Congo 1960-61, Gabon 1961, Ivory Coast 1957-58 (second survey), Mali 1960-61, Uganda 1959 and Upper Volta 1960-61;
Group 3. 7 populations, namely Botswana 1964 and 1971, Central African Republic 1966, Kenya 1969, Lesotho 1966, South African Bantu 1951 and Swaziland 1966;

TABLE 3.7: **Group Logit Deviations ($D_A(x)$) of the additional 18 Female Populations compared with the Total Logit Deviations ($D_T(x)$)**

UP TO AGE	Logit Standard of Table 3.1 last column	GROUP 1		GROUP 2		GROUP 3		GROUP 4	
		$D_A(x)$	$D_T(x)$	$D_A(x)$	$D_T(x)$	$D_A(x)$	$D_T(x)$	$D_A(x)$	$D_T(x)$
5	+ .78752	-.134	-.067	-.133	-.097	+.025	+.107	-.058	+.010
10	+ .39983	-.083	-.080	-.105	-.086	+.007	+.014	-.053	-.016
15	+ .14175	+.017	-.001	-.020	-.002	-.005	-.019	+.027	-.003
20	- .06731	+.080	+.061	+.065	+.058	-.008	-.029	+.054	+.015
25	- .25073	+.074	+.064	+.096	+.071	-.010	-.031	+.040	+.007
30	- .42080	+.046	+.027	+.097	+.056	-.010	-.043	-.011	-.012
35	- .58571	+.013	+.008	+.084	+.046	-.018	-.039	-.036	-.024
40	- .75177	-.010	-.017	+.060	+.011	-.015	-.039	-.047	-.036
45	- .92446	-.026	-.028	+.019	-.003	-.013	-.018	-.045	-.032
50	-1.10983	-.021	-.028	-.020	-.026	-.002	-.008	-.015	-.011
55	-1.31447	-.015	-.003	-.059	-.018	-.001	+.019	+.020	+.018
60	-1.54767	+.059	+.068	-.083	-.010	+.050	+.084	+.122	+.086
65	-1.82163	+.095	+.110	-.190	-.006	+.071	+.159	+.186	+.143

Fig. 3.4: The Four Patterns of $D_A(x)$ and $D_T(x)$, Female Populations



Group 4. 12 populations, namely Gambia 1973, Ghana 1970, Kenya 1962, Liberia 1962 and 1971, Malawi 1966, Namibia 1951 and 1961, Niger 1959-60, Nigeria 1963, Sierra Leone 1963 and Uganda 1969.

The 7 populations that are not classified are: Burundi 1965, Madagascar 1966, Malawi 1971-72, Mauritania 1964-65, Rhodesia Africans 1969, Rwanda 1970 and Tanganyika 1967.

3.4 Defining Patterns of Age and Coverage Errors

The above procedure was a process of standardization to put age and coverage errors on a comparable basis with a fixed underlying age structure because relating the errors to the existing underlying age distributions would have made a comparison difficult. Table 3.4 and Fig. 3.1 show four defined patterns of 'group' logit deviations obtained by the use of the 'conditional overall' average as a standard for 'group' averages. The 'group' logit deviations, $D_G(x)$, represent error structures which reflect small distortions due to differences of real fluctuations between intra-group populations; but substantial distortions due to inter-group differences of real fluctuations still remain. The use of the 'conditional overall' average which is free from distortions due to most of the inter-group differences of real fluctuations and related to a fixed age structure, generates 'overall' logit deviations, $D_o(x)$, shown in Table 3.5 and Fig. 3.3. The overall logit deviations reflect error structures that are free from distortions due to most of the differences in real fluctuations indicated in individual and logit deviations. Thus, the overall error structure shown in Table 3.5 represents a component of errors that are common in the four error patterns. What the overall error structure cannot show are the inter-group differences in the four error patterns. Therefore, the sum of the 'group' and 'overall' logit deviations, ie. $D_G(x)+D_o(x)$, defined as 'total' logit deviations, $D_T(x)$, indicates an error structure for each group of censuses and surveys, by sex, which reflects the inter-group error differences and common features and minimal effects due to differences in real fluctuations between the group averages.

As can be seen from Table 3.6 and Fig.3.5, the 'total' logit deviations, $D_T(x)$, are classified into 4 patterns. Each of the 4 patterns represents a distinct structure of age and coverage errors. That the 'total' logit deviations represent genuine and clear patterns of age and coverage errors is shown by the high consistency of three sets of logit deviations. The logit deviations for individual populations of each group of censuses and surveys (see Tables 3.8 (a) to 3.8 (d) and Appendix Table 3.3(a) to 3.3(d)) follow the same pattern. These logit deviations were obtained by use of conditional overall average as a standard for individual distributions. The same standard for individual distributions is used for the group average and the resultant group logit deviations are similar in pattern to the logit deviations of individual populations of the same group (see Tables 3.8 (a) to 3.8 (d)), as well as to the total logit deviations (see Tables 3.4 and 3.6). Furthermore, as expected, patterns of individual, group, overall, 'total' logit deviations derived from the male populations agree very closely with the logit deviations obtained from the female populations. This high consistency of the three types of logit deviations of the same group and also of the results from sexes is very powerful evidence to suggest that the patterns of errors are clear and therefore cannot be regarded as dividing out a continuum where less clear structures would result.

However, it is possible that due to random scaling and timing errors, the patterns discerned are a part of a range of errors. For instance, if a census were held for three months, say, from the first of July to the thirtieth of September 1973, those born after the 1st. July 1943 would

Figure 3.5: Four Patterns of Total Logit Deviations, $D_T(x)$

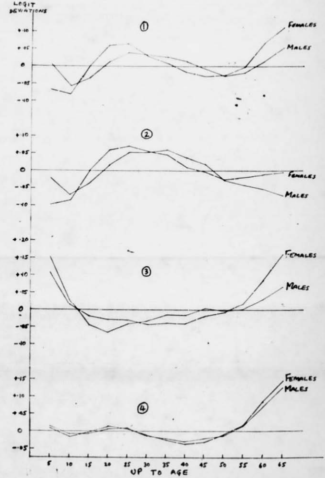


TABLE 3.8(a): Patterns of logit deviations for each survey in Group 1

Under Age	ANGOLA 1950		ANGOLA 1960		DAHOMEY 1961		ETHIOPIA 1965		GHANA 1960		GUINEA 1955	
	F	M	F	M	F	M	F	M	F	M	F	M
5	-.053	-.055	-.070	-.066	-.019	.030	-.047	.008	-.032	-.059	-.060	.010
10	-.002	.001	-.032	-.017	-.025	-.024	-.042	-.018	-.002	-.012	-.032	-.028
15	.008	.018	-.004	.017	.005	-.021	-.007	-.011	.010	.014	.039	.002
20	.013	.031	.027	.032	.027	-.004	.020	-.011	.022	.026	.021	-.006
25	.014	.007	.038	.022	.013	.010	.038	.011	.007	.019	.022	.009
30	.020	-.002	.040	.013	.000	.008	.038	.021	-.004	.011	.011	.013
35	.016	-.000	.027	.004	-.003	.013	.010	.005	-.023	-.010	.030	.032
40	.013	-.006	.021	-.002	-.002	-.003	.027	.000	-.013	-.008	.009	.021
45	-.003	-.016	.003	-.014	.008	.002	-.018	-.012	-.022	-.023	.016	.016
50	-.011	-.016	-.007	-.008	.006	-.001	.027	.022	.005	-.002	-.013	-.002
55	-.015	.004	-.021	.002	.013	.003	-.047	-.006	.009	.001	-.001	-.003
60	-.000	.034	-.024	.018	-.022	-.013	.001	-.009	.045	.042	-.041	-.063
65	-.049	.054	-.089	.005	-.018	-.010	--	--	.054	.042	-.007	-.058

Under Age	MOZAMBIQUE 1950		MOZAMBIQUE 1960		SENEGAL 1960/61		TOGO 1958-60		GROUP 1 $D_G(x)$	
	F	M	F	M	F	M	F	M	F	M
5	-.065	-.078	-.057	-.059	-.041	-.029	-.048	.025	-.046	-.026
10	-.029	-.020	-.035	-.028	-.025	-.041	-.055	-.054	-.029	-.024
15	-.020	-.019	-.020	-.015	.026	-.001	.015	-.012	.005	-.002
20	.020	.025	.031	.032	.026	.024	.056	.014	.028	.016
25	.040	.038	.041	.035	.023	.028	.039	.021	.027	.019
30	.054	.054	.039	.035	-.009	.019	-.007	.006	.015	.016
35	.034	.050	.039	.032	-.012	.004	-.001	.009	.006	.011
40	.018	.031	.030	.026	-.012	.007	-.007	-.005	.002	.015
45	-.015	-.010	.011	.015	.004	.014	.006	-.003	-.007	-.005
50	-.028	-.054	-.012	-.008	.001	.007	-.009	-.012	-.008	-.009
55	-.014	-.035	-.022	-.024	.008	-.001	.002	-.005	-.004	-.007
60	.005	.017	-.046	-.041	.011	-.031	.009	.016	.011	-.005
65	-.103	-.011	-.030	-.023	.041	-.042	.046	.049	.011	.002

TABLE 3.8(b): Patterns of logit deviations for each survey in Group 2

Under Age	CHAD 1963/64 F	M	GABON 1961 F	M	MALI 1960/61 F	M
5	-.104	-.038	-.120	-.096	-.043	-.054
10	-.082	-.076	-.051	-.043	-.020	-.028
15	.005	-.036	-.006	-.021	.004	.007
20	.047	.011	.037	.039	.014	.024
25	.069	.059	.059	.052	.019	.026
30	.065	.079	.080	.069	.026	.024
35	.054	.074	.080	.084	.032	.023
40	.026	.048	.042	.074	.028	.023
45	.022	.029	.013	.044	.016	.010
50	-.007	-.017	-.021	-.022	.001	.000
55	-.029	-.052	-.038	-.062	-.013	-.005
60	-.066	-.083	-.077	-.117	-.063	-.052
65	-.112	-.197	-.096	-.174	-.103	-.094

Under Age	UGANDA 1959 F	M	UPPER-VOLTA 1960/61 F	M	GROUP 2 $D_G(x)$ F	M
5	-.062	-.089	-.060	-.007	-.070	-.054
10	.008	-.008	-.038	-.016	-.036	-.035
15	.007	.019	.015	.007	.004	-.005
20	.004	.025	.036	.006	.025	.020
25	.012	.023	.026	.009	.034	.033
30	.030	.032	.021	.002	.043	.041
35	.032	.025	.027	.011	.045	.044
40	.040	.033	.008	.001	.030	.038
45	.024	.018	.017	-.005	.018	.023
50	.007	.011	-.007	.006	-.006	-.008
55	-.020	-.023	.003	-.003	-.020	-.029
60	-.083	-.064	-.047	-.012	-.067	-.068
65	-.153	-.125	-.093	-.017	-.106	-.118

TABLE 3.8(c): Patterns of logit deviations for each survey in Group 3

Under Age	BOTSWANA 1964 F	BOTSWANA 1964 M	BOTSWANA 1971 F	BOTSWANA 1971 M	KENYA 1969 F	KENYA 1969 M
5	.137	.111	.146	.120	.086	.073
10	.039	.035	.077	.060	.051	.054
15	-.020	-.010	-.010	.007	-.001	.014
20	-.056	-.045	-.069	-.060	-.043	-.031
25	-.056	-.048	-.083	-.071	-.049	-.058
30	-.045	-.042	-.061	-.056	-.045	-.053
35	-.025	-.024	-.041	-.045	-.031	-.049
40	-.018	-.017	-.018	-.018	-.017	-.034
45	.000	.007	.002	-.002	-.003	-.017
50	.008	.013	.005	.014	.016	.012
55	.018	.016	.024	.022	.018	.038
60	.015	.005	.027	.030	.018	.050
65	.036	-.014	.064	.056	.019	.053

Under Age	LESOTHO 1966 F	LESOTHO 1966 M	SWAZILAND 1966 F	SWAZILAND 1966 M	GROUP 3 $D_G(x)$ F	GROUP 3 $D_G(x)$ M
5	.167	.222	.126	.077	.134	.122
10	.087	.103	.065	.045	.064	.061
15	-.024	-.045	-.012	-.011	-.013	-.012
20	-.086	-.127	-.054	-.049	-.062	-.062
25	-.088	-.101	-.059	-.032	-.068	-.062
30	-.058	-.053	-.067	-.031	-.056	-.047
35	-.052	-.030	-.046	-.009	-.040	-.032
40	-.015	.008	-.034	-.024	-.020	-.017
45	.017	.033	-.005	.004	.003	.005
50	.017	.017	.013	.022	.012	.016
55	.011	-.004	.019	-.002	.018	.014
60	.021	-.024	.053	.009	.027	.014
65	.057	-.028	.103	.015	.060	.018

TABLE 3.8 (d): Patterns of logit deviations for each survey in Group 4

Under Age	KENYA 1962		MALAWI 1966		NAMIBIA 1951	
	F	M	F	M	F	M
5	.019	.061	.014	.031	.035	-.125
10	.031	.051	.024	.032	.042	.042
15	.004	-.005	.015	.019	-.010	.104
20	-.010	-.039	-.021	-.024	-.023	.092
25	-.019	-.036	-.019	-.032	-.028	-.016
30	-.025	-.032	-.012	-.026	-.016	-.096
35	-.029	-.030	.005	-.016	-.020	-.113
40	-.013	-.015	.000	-.016	-.019	-.077
45	-.009	-.009	.026	.011	-.021	-.053
50	.006	.004	-.008	.003	.012	.026
55	.005	.009	.000	.013	.021	.078
60	.040	.041	-.024	.005	.027	.139
65	.040	.043	.015	.036	.016	.167

Under Age	NAMIBIA 1961		UGANDA 1969		GROUP 4 $D_G(x)$	
	F	M	F	M	F	M
5	.037	-.049	.038	.015	.036	-.017
10	.035	.002	.026	.023	.034	.024
15	-.004	.011	-.004	.002	.002	.024
20	-.022	.014	-.021	-.010	-.018	.009
25	-.027	.014	-.019	-.013	-.030	-.011
30	-.019	.008	-.020	-.017	-.025	-.028
35	-.028	-.010	-.022	-.031	-.025	-.037
40	-.017	-.019	-.005	-.025	-.018	-.029
45	-.015	-.028	.002	-.016	-.011	-.019
50	.001	-.013	.020	.013	.009	.006
55	.021	.017	-.005	.014	.016	.025
60	.038	.052	.010	.045	.029	.053
65	.070	.107	-.010	.053	.043	.077

be recorded as below 30 years; but owing to carelessness, forgetting or misunderstanding of instructions, some enumerators might record age 30 for those born between July and September 1943 while other enumerators would record age 29 in accord with instructions. This timing error would not have happened had the Census been on one night only. Furthermore, the timing error causes scaling error because these two groups of people are classified under two age groups - 25-29 and 30-34 - and thus analysed in different age groups which have arithmetic means that are five years apart. Supposing, further, that in two countries censuses were held at the same time for three months, and enumerators in one country followed the given instructions and in the other ignored them, we would find an upward bias in age group 30-34 in the former country and a downward bias in the 25-29 group in the latter country. However, the effects of such erratic errors tend to cancel out given the whole country's population. For example, if for the above argument, age group 25-29 loses population to 30-34 group, the decreases in the former would be made good by the losses of age 20-24 to it. For the same reason, the 30-34 group would lose to age group 35-39 much of what it gained from the 25-29 group. Besides, this compensation of timing and scaling errors becomes more complete in the process of averaging many populations enumerated in censuses and surveys of varying length and different dates.

In order to define the error patterns, it is necessary to express the total logit deviations in natural terms. Thus, Table 3.6 and Fig.3.5 have been converted into Table 3.9 and Fig.3.6, respectively. Table 3.9 and Fig. 3.6 show ratios of 'modified' to stable distributions. These ratios indicate the extent of age and coverage errors in natural terms, despite the fact that the 'total' logit deviations (in Fig.3.5) portray the error patterns more distinctly than the ratios. As can be seen from

TABLE 3.9: **Ratios of the Modified Group Average to the Stable Distribution (level 40, G.R.R. = 3.0)**

Age Group \ Survey Group	1		2		3		4	
	M	F	M	F	M	F	M	F
0-4	.99	1.12	1.03	1.17	.77	.83	.97	.98
5-9	1.19	1.11	1.17	1.06	1.20	1.16	1.06	1.07
10-14	.93	.71	.90	.69	1.27	1.13	1.00	.96
15-19	.78	.70	.75	.71	1.11	1.05	.94	.91
20-24	.87	1.00	.81	.95	.86	1.00	.99	1.05
25-29	1.08	1.25	1.02	1.13	.93	1.04	1.14	1.11
30-34	1.04	1.14	1.02	1.11	.87	.94	1.02	1.05
35-39	1.10	1.14	1.20	1.25	.99	.96	1.02	1.04
40-44	1.13	1.03	1.14	1.09	.87	.85	.92	.93
45-49	1.08	.96	1.25	1.10	1.04	.93	.93	.85
50-54	.92	.86	1.01	.93	.97	.87	.87	.87
55-59	.86	.73	.96	.94	.90	.79	.81	.78
60-64	.91	.99	.96	.97	.96	.91	.96	.98
65+	1.10	1.23	.87	.98	1.13	1.35	1.26	1.31

Figure 3.6: Ratios of 'Modified' Group Averages to Stable Population

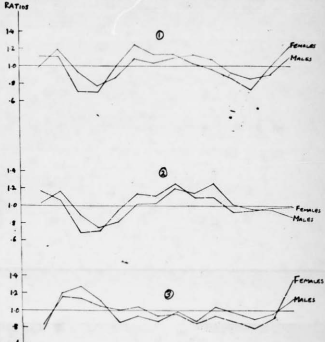


Table 3.9 and Fig. 3.6, the four patterns of age and coverage errors for both sexes in tropical African censuses and surveys may be expressed as follows:

(1) survey group with error pattern 1 shows excess proportions in childhood ages 0-10, middle ages 20 to 50 and very advanced ages above 65; plus deficits in the teens, 10-19, early twenties (20-25) and old ages (50-65);

(2) survey group with error pattern 2 displays surplus proportions at ages below 10 and between 25 and 45 years; and deficiencies in teens (10-20), early twenties (20-25) and above 55 years old;

(3) survey group with error pattern 3 exhibits an exaggeration of proportions between ages 5 and 20 and in advanced ages above 65; and deficits at infancy and early childhood ages (0-5) and from 20-65 years;

(4) survey group of error pattern 4 indicates surpluses in the 5-10, 25-40 age spans and above age 65 years; and deficiencies at very young ages of 0-5, late teens (15-19), late middle ages and early old ages (40-65).

3.5 Features of the Error Patterns

A comparison of these four patterns of age and coverage errors shows common features worth mentioning. First, Fig.3.6 clearly shows that the ratios of the 'modified' to the stable distributions for males are very close to those of the females in each of the four error patterns, especially in pattern 4. This closeness indicates that the ages of males and females in the same survey were recorded in similar ways. This result strengthens the belief held by many demographers with experience of African data that there is scanty evidence to suggest marked sex differentials of age and coverage error patterns in the same African population. However, it seems certain that the sizes of the errors vary with sex. For example, it can be seen from Fig. 3.6 that bigger errors are shown for females than for males in almost all age groups in survey groups 1 and 2 and after age 35 in the survey group 3.

The second feature common to almost all the error patterns is the exaggeration of ages at advanced ages. With the exception of error pattern 2, all the ratio curves exhibit excess proportions of population at age 65 and above. This common finding is hardly surprising in view of the important status of old people in many African societies. It is known that many people, especially men, deliberately overstate their ages in order to be more important in their societies. Perhaps, another cause of surplus proportions in advanced age groups is that since many people in tropical Africa become grand-parents at fairly early ages, census takers would over-estimate their ages if grand-parenthood, like parity, was used by enumerators as a basis of estimating ages. It is also possible that the poor illiterate peasants just look older to the better educated enumerators.

Another significant feature of the patterns of age and coverage errors shown in Fig. 3.6 is the broad similarity between the early part of error patterns 1 and 2. Both patterns indicate that ages 10-20 were avoided in favour of lower and higher ages. The ratio curves for both error patterns display big excesses of proportions in ages 25 and 45. These excesses are probably due to basing the estimation of ages on the marital status and parity of respondents. Because some kind of normative, rather than true, age of marriage exists in the minds of interviewers and enumerators, there is a tendency to assign higher ages to married people than they possess. In addition, in many African censuses and surveys, enumerators and interviewers base their estimation of ages on the parity of women and tend to represent women with many children as older than they actually are. However, it must be mentioned that these two error patterns differ distinctly in the late middle and old ages (45 and above). Whilst ages 45 to 50 and 65 and above show excess proportions in error pattern 1, the same age spans display deficits in error pattern 2.

A striking contrast to what has been noted about error patterns 1 and 2 is noticeable in error pattern 3. As can be seen from Table 3.9 and Fig.3.6, unlike error patterns 1 and 2, error pattern 3 exhibits deficits of infants and young children ages (0-5) and of the middle ages 25 to 45. The deficiencies observed in age group 0-4 are scarcely unexpected in tropical African conditions where taboos about reporting and counting infants and young children still exist and where infants may not be regarded as part of the population. The deficits shown in ages 20 to 45 are quite unexpected, though it may be mentioned that part of the deficits probably emanated from the use of historical event calendars in these surveys. A more plausible cause of the deficits is that during the censuses of Botswana, Lesotho and Swaziland, a large fraction of people in the working age groups was away from their homes working in South Africa. These people's ages were recorded through their families who most likely did not know their actual ages, and hence crude guesses were recorded. It is also probable that families refused to report the relatives who went to work in South Africa illegally, for fear of government prosecution, thus causing under-enumeration of these age groups. The avoidance of ages 20 to 65 appears from Fig. 3.6 to be largely responsible for creating a bulge of population aged 5 to 20 and for some of the overstatements of ages in favour of 65 and above.

The curves of the fourth error pattern share some common features with the curves of patterns 1 and 2, as already noted, but there are features which make the former curves distinct from the latter curves. It can be seen from Fig. 3.6 that although the bulge of pattern 4 curves starts at the same age (15) as that of patterns 1 and 2 curves, it disappears sooner, namely after age 25 compared with age 35 for pattern 1 and age 45 for pattern 2. Also to be noted is that the bump of the curves of pattern 4 (from age 30 to 50) occurs at the same age as part of the bump of the pattern 3 curves.

In addition, the fourth error pattern is unlike the rest of the patterns in that it shows small errors on average in association with its particular form. This is evident from the ratio curves in Fig. 3.6 which are not sharp or do not vary a lot from the unity line. The lack of sharpness and the closeness to unity of the ratio curves in error pattern 4 reflects the closeness of 'total' logit deviations, $D_T(x)$, to zero (as can be seen from Table 3.6) and hence indicate that the 'modified' age structure (see Appendix Table 3.2) of survey group 4 is smooth and close to a stable age distribution. The probable reasons for the small errors are that the age heaping saw-tooth effect on the total error is small and that most of the other errors in the reported age distributions cancel out. It may further be observed that although the small errors do not necessarily mean few age misstatements, they suggest that the reported age structure of the survey group 4 was less distorted than those of other groups. This observation will become clear later when an illustrative example drawn from survey group 4 is discussed.

Further to that which has been noted about the four pattern errors, three general remarks are relevant. The first comment relates to the reassuring evidence about the existence of the patterns of age and average errors, that where two censuses were held in a single country, the tendency is for these two censuses to fall in the same group of error pattern. The censuses of Angola and Mozambique in 1950 and 1960 show errors of pattern 1, Botswana 1964 and 1971 censuses of pattern 3 and Namibia 1951 and 1960 censuses belong to pattern 4. This feature of constant error pattern in two successive censuses in a single country has been found elsewhere in the developing countries, namely in Turkey by Demeny and Shorter (1968) and in Burma by Bernadelli (1941). However, the 1969 censuses of Kenya and Uganda had different error patterns from the earlier censuses of 1959 and 1962 probably because of variation in coverage and questionnaires. It is known that the Kenyan 1962 census did not cover the North-Eastern part (about a fifth in area) of the country due to the boundary disputes that were going on at the time of the census, and the questions on age asked in the Ugandan 1959 census were different from those used in 1969.

Another general remark to be made on the features of the error patterns is the relation between the errors of one pattern and the way in which the surveys of the group were organized. The patterns of errors due to age misstatements and omissions show that the survey groups are dominated by inquiries conducted under the same supervision or organization. Eleven out of fifteen surveys (original and those added later) in group 1 were organised by either the French or Portuguese (see Table 3.8(a) and Appendix Table 3.3(a)). In the original group 2 (displayed in Table 3.8(b)), all the surveys, except Uganda 1959 census, were French supervised. The overlap of the French dominance in the supervision and organisation of surveys in groups 1 and 2 may explain the similarity of error patterns in the young and early middle ages, as already observed, in Fig. 3.6. Furthermore, all the censuses of the original group 3 were British oriented and under one overall adviser, Dr. Blacker. In addition, out of the twelve censuses and surveys of group 4, nine were British, two South African and only one was French administered. It seems certain that the different tactics, methods and instructions used by different organisers in tropical Africa created wide variations in the way in which people responded to questions on ages among questions on demographic aspects. For instance, in the Portuguese areas and Namibia, the enumeration was done on the basis of assemblies; the French carried out national sample surveys using interviewers, while the British conducted censuses using enumerators.

Lastly, it is pertinent to note that there is hardly evidence in our results to suggest that the size of the error depends on age. It has been noted elsewhere (e.g.Demeny-Shorter study of Turkish data, 1968) that owing to a bigger problem of memory lapse and illiteracy in older people, bigger misstatements are detected in older ages in developing countries. This feature of age errors has been found to exist in African censuses in respect of an age heaping problem (see Chapter 2). However, as can be seen from Tables 3.6 and 3.9 and Figs. 3.5 and 3.6, the error patterns do not display this phenomenon. Although the errors in ages 10 to 60 are bigger than those in younger ages 0 to 10, there is scarcely evidence to suggest progressively bigger errors within the 10 - 60 age period. In fact the errors in ages 10-60 are even bigger than those above age 60. The reason for the lack of a clear trend is probably that age heaping errors have cancelled out as a result of averaging process mainly because the patterns of age heaping in individual African censuses vary, as already has been discussed in the previous chapter.

3.6. Illustrative Example

It is relevant at this juncture to show how these patterns of errors may be used to adjust an age structure of an African survey or census. We suggest the following procedure: first, by use of the logit transformation and the 'conditional overall average' (see Table 3.3) as a standard, a curve is fitted to the reported age distribution of the survey or census using equations 3.1, 3.2 and 3.3. Secondly, the resulting logit deviations (calculated by subtracting the logit fitted from the logit reported) are compared with the four model sets of total logit deviations, $D_T(x)$, shown in Table 3.6. The model set that is closest in pattern to the former logit deviations is selected as the appropriate model error pattern to be used to correct the reported age structure. Thirdly, before we use the model total logit deviations to correct the reported age distribution of the survey or census, it is necessary to allow for the difference in the size of the error as reflected in the logit deviations of individual surveys from that reflected in the selected total logit deviations. To do this, we scale up or down the model total logit deviations to give the same average as the logit deviations of the individual survey. The 'scaled' total logit deviations are added to the logit standard (ie. the second column of Table 3.7) and the resultant sum is converted back to percentage distribution. This distribution is then divided by the standard distribution (the stable distribution seen in Table 3.1) to give ratios that reflect the pattern of error of the concerned group of surveys, ie. they have a similar shape to the respective ratios in Table 3.9 but differ in level because of the error size correction. Finally, we use the ratios which have been corrected for the size of the error to adjust the reported age percent distribution.

Taking Uganda female age data from the 1969 census as an example, we find that from the patterns of logit deviations in Table 3.8(d), the census was characterised by an age and coverage error pattern very similar to survey group 4 in Table 3.6. Hence we shall use corrected ratios of pattern 4 to adjust the reported age structure of Uganda's 1969 census (as may be seen in Table 3.10) by dividing the ratios into the corresponding percentages of the age structure. Column 3 displays the results of column 1 divided by column 2. Since the estimated percentages in column 3 do not add up to 100.00, they are scaled up to do so in the final estimate in column 4.

The next question is to examine whether column 4 of Table 3.10 is a plausible estimate of the true age percent distribution of Uganda females in 1969. To do this, it is necessary to indicate whether the estimated age

TABLE 3.10: Application of the Patterns of Errors to Adjust Uganda Female Age-Structure of 1969 Census

Age Group	Reported Distribution 1	Pattern 4 Ratios Corrected for size of Error 2	Estimated Structure 3 = 1 ÷ 2	Final Estimated Structure 4
0-4	19.74	.988	19.98	20.01
5-9	15.54	1.050	14.80	14.82
10-14	11.04	.969	11.39	11.41
15-19	8.77	.938	9.35	9.36
20-24	8.08	1.034	7.81	7.82
25-29	8.06	1.079	7.47	7.48
30-34	6.34	1.037	6.11	6.12
35-39	5.04	1.027	4.91	4.92
40-44	4.07	.950	4.28	4.29
45-49	3.17	.895	3.54	3.55
50-54	3.07	.906	3.39	3.40
55-59	1.73	.846	2.04	2.04
60-64	1.94	.983	1.97	1.97
65+	3.39	1.210	2.80	2.80
TOTAL	99.98		99.84	99.99

distribution reflects plausible trends of past fertility, mortality and migration of Uganda. The estimated proportions in age groups up to age 20 reflect high and increasing fertility of Uganda females twenty years prior to 1969. It is satisfying to note that there is an agreement between this observation on the estimated age structure and estimates of fertility reported in other studies. For instance, the total fertility of the Uganda Africans was estimated by use of the Brass P/F ratio method to have increased from 5.8 in 1959 to 6.8 in 1969 (see Ntozi, 1973, p.75).

In addition we are reassured on the plausibility of our estimates by the consistency of the estimated age distribution with the events of Uganda's demographic history between 1945 and 1969. The estimated age structure mirrors evidence that there were no major catastrophies like wars, epidemics or famines to adversely influence the trend of mortality and fertility of Uganda from 1948 to 1969 on a national scale. In fact, during this period, Uganda is known to have enjoyed a period of economic prosperity with a boom of prices of coffee - the mainstay of Uganda's economy - during and after the Korean war and political stability. Though there was a short period of migration of political refugees to Uganda from Rwanda and Zaire, this seems not to have had a marked impact on the age distribution, perhaps because the refugees were in families of all age groups, rather than individual migrants of selected ages as in labour migrations.

The estimated age structure of Uganda does not show any indication of a baby boom shortly after the second war or a marked deficit in the cohorts born in the war probably because the war was too far away to be felt by the bulk of the population of Uganda. Furthermore, a smooth trend of gradual declining sizes of proportions of female population in older groups is noticeable above age 30, perhaps implying the lack of major incidents of demographic interest between 1905 and 1940. Famines, epidemics and civil wars are known to have occurred in different areas of Uganda at different times between 1900 and 1940, but no major national demographic episodes are known during this period. However, it must be said that the available information on the demographic history of Uganda before 1940 is scanty and shaky and it can not be taken as conclusive evidence that the estimates of our example are very near the truth.

3.7. How valid are the assumptions?

The four patterns of age and coverage errors were obtained under two assumptions. The first assumption made is that real fluctuations (fertility, mortality and migration) were dissimilar in different censuses and surveys. It is not possible to know the actual long term trends of fertility, mortality and migration of tropical African countries because of the lack of vital registration systems in the region. However, it is likely that for various reasons, such as wide differences in dates and places of censuses and surveys, trends of fertility, mortality and migration were different and sometimes in opposite directions in different countries. Thus, it is plausible that by averaging age distributions of different surveys most of the irregularities created by the fluctuations cancel out despite possible consistent and non-cancelling effects due to migration and the reporting of migrants.

The second assumption is that age and coverage errors are similar in different surveys in tropical Africa. The study of digit preferences in reporting ages in 13 tropical African censuses reported in the previous chapter has shown that several censuses have in common similar patterns of this type of age errors. Besides,research in age data of Burma and Turkey, countries with defective data comparable to the African experience, has found age errors of successive censuses constant. Therefore, whereas this assumption may not be valid for all the censuses and surveys in tropical Africa, it is plausible to categorize these surveys under the above four patterns of errors for reasons already given in this chapter.

An advantage of our procedure is that it does not depend on stable population theory to derive the four error patterns, since no one knows whether tropical Africa has had constant fertility and mortality in the past. Instead, we do know that migration has been appreciable in many areas of Africa (stable population theory assumes nil migration), and research has so far indicated that mortality has tended to decline in the recent past due to better medical and sanitary facilities. Also, less certain evidence from past studies points to possible increases in fertility levels in tropical Africa.

3.8. Conclusion:

By the use of a standardization process involving averages of age distributions from different censuses and surveys of tropical Africa and by the expression of these age distributions in terms of logits, the present work shows that there are at least four patterns of logit deviations. Investigations made into these logit deviations strongly suggest that they represent true age and coverage error patterns rather than being a part of a random continuum of misreporting. In addition, it has been found that these patterns are common in censuses and surveys which used similar collection procedures. This finding suggests a strong and varied influence of census and survey organisation in the structure of age and coverage errors in tropical Africa. Furthermore, our analysis has produced convincing evidence to indicate that the patterns of the errors in male and female populations in the same surveys or censuses are similar. This result suggests a similar age misstatement and misrecording of errors in both sexes. The question of sex differential age misreporting is examined more closely in the next chapter.

However, it must be pointed out that in broad terms groups 1, 2 and 4 are similar in pattern except in old age. Thus, a general description of the age and coverage errors in tropical Africa might be given as follows:

(i) Under-enumeration of the very young ages,

(ii) understatement of the teens,

(iii) overstatement of the twenties, and

(iv) exaggeration of the old ages.

This is in conformity with the idea that there is an African pattern of error as discussed by Van de Walle (1968). In fact, we have demonstrated that this similarity conceals differences.

CHAPTER FOUR

SEX DIFFERENTIAL ERRORS IN AGE REPORTING

4.1 Introduction

Age and coverage errors which occurred in most of the national demographic inquiries of tropical Africa in the last three decades have been categorised into several distinct patterns by the analysis of the previous chapters. Another aspect of age and coverage errors in tropical Africa that deserves to be studied is the sex differential in the errors. Various demographic studies have suggested that there might exist differences in the way male and female age misreporting operates. For instance, it has been noted that in some age groups males tend to report higher ages than females, while in other age groups the opposite holds. The methods employed in the two previous chapters have been used to examine the sex differences. However, it is also possible to devise approaches which are based on other ideas and data, largely independent of the earlier methods. In this chapter, a technique is presented based on the use of orphanhood data (see Brass and Hill, 1973) and applied in various ways.

4.2 Orphanhood Data

Recently, efforts by R. Clairin in the French speaking Africa and J. Blacker in English speaking Africa, have yielded data on orphanhood from at least eight African countries. Because the questions asked in the censuses and surveys - "Is your father alive?" and "Is your mother alive?", were straightforward and required only simple answers - "No", "Yes", or "Don't know", the observations are considered to be fairly reliable. However, an examination of the proportions of children reporting their parents alive reveals quite substantial differences between the male and female populations, by age group, in tropical African countries. This can be seen

TABLE 4.1: Reported Proportions of Children with Surviving Mothers

AGE GROUP	BOTSWANA 1971 M	F	CHAD 1963-5 M	F	WEST CAMEROONS 1964-5 M	F	GAMBIA 1973 M	F
5-9	.973	.973	.944	.947	.948	.948	.955	.957
10-14	.958	.961	.900	.902	.897	.898	.926	.928
15-19	.932	.934	.811	.797	.801	.829	.865	.859
20-24	.892	.884	.713	.697	.734	.672	.792	.770
25-29	.832	.813	.627	.585	.600	.539	.683	.665
30-34	.771	.749	.526	.451	.471	.418	.553	.514
35-39	.701	.683	.444	.380	360	.268	.474	.436
40-44	.607	.591	.283	.248	.263	.178	.351	.310
45-49	.519	.497	.224	.167	.147	.093	.275	.247
50-54	.393	.381	.140	.095	.069	.048	.186	.142
55-59	.305	.290	.107	.041	.040	.024	.131	.121

AGE GROUP	KENYA 1969 M	F	MALAWI 1971-2 M	F	UGANDA 1969 M	F
5-9	.974	.975	.977	.971	.970	.972
10-14	.954	.960	.951	.957	.945	.954
15-19	.920	.924	.926	.932	.892	.902
20-24	.872	.864	.911	.846	.831	.819
25-29	.808	.788	.784	.759	.742	.723
30-34	.724	.686	.685	.711	.643	.605
35-39	.639	.602	.601	.567	.552	.499
40-44	.529	.476	.452	.462	.425	.360
45-49	.414	.368	.392	.367	.328	.268
50-54	.278	.244	.292	.221	.205	.158
55-59	.220	.177	.179	.152	.147	.112

TABLE 4.2: Reported Proportions of Children with Surviving Fathers

Age Group	BOTSWANA 1971		CHAD 1963-5		WEST CAMEROONS 1964-5		GAMBIA 1973	
	M	F	M	F	M	F	M	F
5-9	.915	.913	.910	.912	.870	.873	.924	.921
10-14	.885	.879	.826	.827	.783	.793	.871	.869
15-19	.840	.816	.683	.651	.648	.675	.779	.752
20-24	.747	.721	.515	.500	.554	.505	.661	.606
25-29	.641	.620	.382	.380	.397	.359	.506	.471
30-34	.522	.504	.261	.267	.265	.224	.372	.303
35-39	.431	.415	.197	.190	.179	.142	.256	.224
40-44	.340	.299	.127	.104	.106	.081	.170	.138
45-49	.249	.218	.084	.067	.058	.048	.111	.097
50-54	.161	.143	.044	.034	.017	.009	.066	.059
55-59	.113	.101	.038	.016	.018	.021		

Age Group	KENYA 1969		MALAWI 1971-2		UGANDA 1969	
	M	F	M	F	M	F
5-9	.933	.935	.935	.948	.951	.919
10-14	.896	.901	.928	.919	.909	.914
15-19	.832	.837	.873	.862	.828	.833
20-24	.744	.739	.793	.765	.724	.708
25-29	.634	.633	.696	.653	.600	.574
30-34	.524	.500	.534	.531	.478	.437
35-39	.415	.404	.427	.428	.377	.332
40-44	.300	.281	.297	.294	.256	.211
45-49	.211	.198	.276	.179	.178	.146
50-54	.124	.118	.174	.104	.102	.079
55-59	.088	.085	.059	.064	.066	.057

in Tables 4.1 and 4.2. The observations are used to calculate ratios of the proportions of male to female children reporting surviving parents shown in Tables 4.3 and 4.4 for seven tropical African countries, namely, Botswana 1971, Chad 1963-65, West Cameroons 1964-65, Gambia 1973, Kenya 1969, Malawi 1971-72, and Uganda 1969. It can be seen that the proportions by sex are close, but slightly lower for males in the age groups 10-14. Then, the proportions for males are higher than those for females from age 20 to 50. The gap between the proportions for males and females is clearly shown to widen with age.

Since sex at birth is random in relation to age of parents, this pattern of differences in the reporting by male and female children may be explained by three reasons: (i) that the errors in the reporting of ages have a strong sex differential; (ii) that parents with more male children tend to live longer; or (iii) that males over-report survivorship and/or females under-report. In the light of what is known about tropical Africa, there seem to be no plausible reasons for accepting that the second or third explanation could cause the large deviations between males and females. Instead, it is more attractive to accept the proposition that the reported pattern of sex ratios is defective because of errors in the age distributions of males and females. We shall, therefore, utilise the proportions of each sex, reporting parents alive, to estimate the sex differentials in the age errors.

4.3. Estimating relative ages from the reported proportions of both sexes with surviving parents

A simple method for estimating age discrepancies by sex is to use the reported proportions of both sexes with mothers (or fathers) alive, by age groups. The underlying assumptions of this method are: (i) that

TABLE 4.3: <u>Ratios of Reported Proportions of Male to Female Children with Mothers Alive</u>

AGE GROUP	BOTSWANA 1971	CHAD 1963-5	WEST CAMEROONS 1964-5	GAMBIA 1973	KENYA 1969	MALAWI 1971-2	UGANDA 1969
5-9	1.00	1.00	1.00	1.00	1.00	1.01	1.00
10-14	1.00	1.00	1.00	1.00	0.99	0.99	0.99
15-19	1.00	1.02	0.98	1.01	1.00	0.99	0.99
20-24	1.01	1.02	1.09	1.03	1.01	1.08	1.01
25-29	1.02	1.07	1.11	1.03	1.02	1.03	1.03
30-34	1.03	1.17	1.13	1.08	1.05	0.96	1.06
35-39	1.03	1.17	1.34	1.09	1.06	1.06	1.11
40-44	1.03	1.14	1.48	1.13	1.11	0.98	1.18
45-49	1.04	1.34	1.58	1.11	1.12	1.07	1.22
50-54	1.03	1.47	1.44	1.31	1.14	1.32	1.30
55-59	1.05	2.61	1.66	1.08	1.22	1.18	1.31

TABLE 4.4: <u>Ratios of Reported Proportions of Male to Female Children with Fathers Alive</u>

Age Group	BOTSWANA 1971	CHAD 1963-5	WEST CAMEROONS 1964-5	GAMBIA 1973	KENYA 1969	MALAWI 1971-2	UGANDA 1969
5-9	1.00	1.00	1.00	1.00	1.00	0.99	1.00
10-14	1.01	1.00	0.99	1.00	0.99	1.01	0.99
15-19	1.03	1.05	0.96	1.04	0.99	1.01	0.99
20-24	1.04	1.03	1.10	1.09	1.01	1.04	1.02
25-29	1.03	1.01	1.11	1.07	1.00	1.07	1.05
30-34	1.04	0.98	1.18	1.23	1.05	1.01	1.09
35-39	1.04	1.04	1.26	1.14	1.03	1.00	1.14
40-44	1.14	1.22	1.31	1.23	1.07	1.01	1.21
45-49	1.14	1.25	1.21	1.14	1.07	1.54	1.22
50-54	1.13	1.29	1.89	1.12	1.05	1.67	1.29
55-59	1.12	2.38	0.87	0.94	1.04	0.92	1.16

the reported structure of proportions of both sexes combined can be described by a smooth, regular curve, and (ii) that the proportions of parents surviving by sex should be the same for any fixed age of child.

The estimation of the relative ages may take two forms. Firstly, the graphical form: the proportions of both sexes are plotted against the corresponding age groups and a smooth curve fitted through the points (see Figures 4.1 to 4.6). Also, from the same graph, the ages on the curve that correspond to the points for each sex are read off. Figures 4.1 to 4.6 illustrate the deviations of the points for males and females from the curve fitted to both sexes.

A disadvantage of the graphical method is that different results will, in general be obtained from the varying curves that may be fitted. Since the curvature is quite gentle, it seems better to apply a simple computational procedure of estimation using linear interpolation. Linear interpolation gives very much the same results as the graphical approach. The reported proportions of each sex with mother (or father) alive are interpolated linearly between the proportions for both sexes in order to obtain the required estimates of related ages. The proportions for both sexes are taken to correspond with the mid-point of the relevant age groups.

The results of the method are displayed in Tables4.5 and 4.6. It should be noted that the ages will contain reporting errors common to both sexes. The tables show that the ages estimated for males are slightly higher before age 15 and lower after age 20 than the estimates for females. The gap between the related ages for the sexes widens at the older years. The results indicate a systematic exaggeration of ages by

Figure 4.1: Reported Proportions of Children with Surviving Mothers - West Cameroons 1964-65

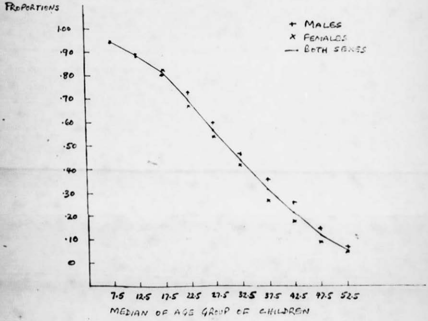


Figure 4.2: Reported Proportions of Children with Surviving Mothers - Chad 1963-65

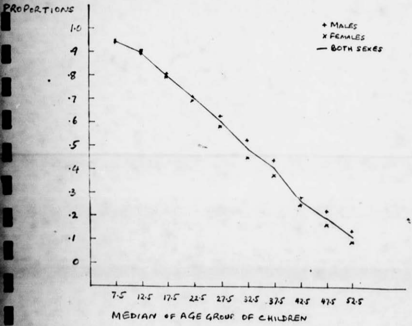


Figure 4.3: Reported Proportions of Children with Surviving Mothers - Gambia 1973

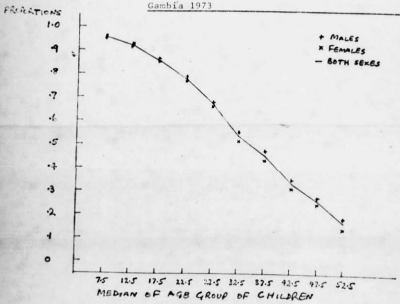


Figure 4.4: Reported Proportions of Children with Surviving Mothers Kenya 1969

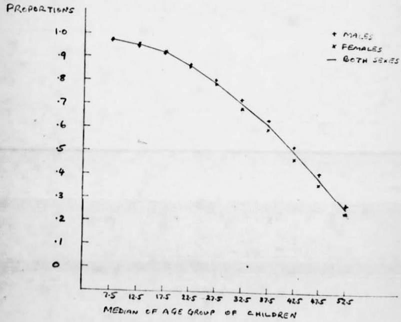


Figure 4.5: Reported Proportions of Children with Surviving Mothers - Malawi 1971-72

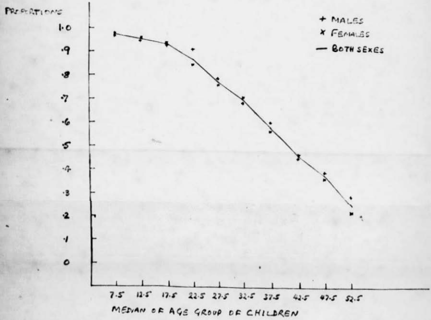


Figure 4.6: Reported Proportions of Children with Surviving Mothers - Uganda 1969

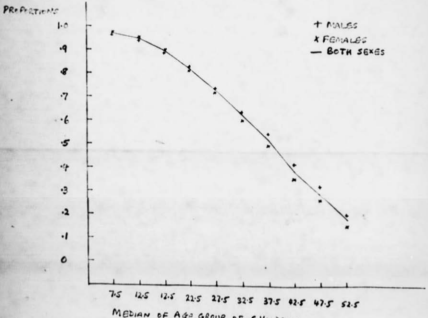


TABLE 4.5: Estimated Relative Ages by Use of Reported Proportions with Mothers Alive

Age Group of Children	Median of Age Group	CHAD 1963-5		WEST CAMEROONS 1964-5		GAMBIA 1973		KENYA 1969		UGANDA 1969	
		F	M	F	M	F	M	F	M	F	M
10-14	12.5	12.3	12.6	12.4	12.5	12.3	12.6	11.6	12.9	11.1	12.9
15-19	17.5	17.9	17.1	16.9	17.9	17.7	17.3	17.2	17.7	17.0	17.8
20-24	22.5	22.9	22.1	23.6	21.0	23.0	21.8	22.8	21.9	22.8	22.1
25-29	27.5	28.4	26.4	28.8	26.2	27.8	27.1	28.0	26.9	28.0	27.0
30-34	32.5	34.9	30.9	33.5	31.4	33.7	31.8	33.6	31.4	33.5	31.6
35-39	37.5	38.6	35.4	40.0	35.9	38.3	36.4	38.3	36.2	38.5	36.1
40-44	42.5	43.8	41.9	44.7	40.3	44.0	41.7	43.7	41.4	44.2	41.3
45-49	47.5	49.4	45.5	49.8	46.3	48.3	46.6	48.4	46.5	48.8	45.9

TABLE 4.6: Estimated Relative Ages by Use of Reported Proportions with Fathers Alive

Age Group of Children	Median Age	CHAD 1963-5		WEST CAMEROONS 1964-5		GAMBIA 1973		KENYA 1969		UGANDA 1969	
		F	M	F	M	F	M	F	M	F	M
10-14	12.5	12.4	12.5	12.2	12.7	12.6	12.4	12.2	12.7	12.2	12.7
15-19	17.5	18.0	17.0	17.0	18.0	18.0	16.8	17.3	17.7	17.3	17.6
20-24	22.5	22.8	22.3	23.2	21.4	23.4	21.4	22.3	22.6	22.8	22.1
25-29	27.5	27.5	27.5	28.2	26.8	28.0	26.9	27.5	27.5	28.0	27.0
30-34	32.5	32.4	32.7	33.7	31.7	34.3	31.4	33.1	32.0	33.5	31.7
35-39	37.5	37.8	37.3	39.0	36.4	38.5	36.7	37.8	37.2	38.5	36.5
40-44	42.5	44.0	41.8	44.0	41.6	44.3	41.7	43.1	42.1	44.1	41.6
45-49	47.5	48.7	46.5	48.2	47.0	48.5	46.9	47.9	47.1	48.7	46.4

males relative to females, at ages above 20. There is also satisfactory agreement between the related ages of males (or females) with surviving mothers and those with surviving fathers, (allowing for sampling variation). This similar pattern of differences between male and female children, regardless of the sex of the parents, supports the view that age error rather than differential survivorship or reporting of numbers alive is the cause of the discrepancies. As already noted, the method relies on the assumption that the structure of the proportions of parents alive as reported by both sexes together is smooth and fairly linear over short sections. However, it may be that the averages of the distorted patterns of the proportions of males and females reporting surviving parents is no smoother than either of the separate components. It may, therefore, be better to develop a method which graduates the data more firmly. This will be done in the next section. If it is further assumed that age and coverage errors are erratic and non-systematic over the total range, the estimates for each sex may be taken as of absolute rather than relative deviations from the true values.

4.4 Estimating 'actual' ages from smoothed proportions with mothers alive

A more heavily smoothed structure of proportions of children with surviving parents, for use in examining sex differentials of age errors, is obtained by applying an orphanhood technique developed by William Brass and Ken Hill (Brass and Hill 1973). On the assumptions that there is no relation between survival of parent and survival of child, or between survival of parent and the number of surviving children and that the level and pattern of fertility and mortality have remained constant over the required time period, the orphanhood method is used to generate estimates of adult survivorship from reports by the children. These are then graduated by the logit system. The smoothed proportions may then be taken as estimates of the true values for the specified age groups although on tight assumptions. The reported values for each sex can then be translated into age error terms.

The computational procedure of the method is illustrated in Table 4.7 by application to the Uganda 1969 census data for mothers alive. Briefly, the calculations are as follows:

(i) Columns 1 to 4: For both sexes together mortality ratios were estimated from the orphanhood technique using the old multiplying factors (Brass 1975, p.60-76). The multiplying factors in column 2 are located in Appendix Table 4.1. This table contains factors for converting proportions of mothers surviving into probabilities of surviving from a base age, B to age B+N. Four panels each corresponding to a defined value of B are given. Within each panel, factors are selected on the basis of two parameters: $\bar{M}$, the mean age of mothers, and N, the median of each age group of children, which is equal to survival interval. Using B=27.5 and $\bar{M}$=26.7, the multipliers in column 2 of Table 4.7 were interpolated between $\bar{M}$=26 and $\bar{M}$=27 columns of the B=27.5 panel.

(ii) Using a value of ℓ_2= .830 (estimated by the Brass Childhood mortality technique -1968), we derive an initial estimate of $\ell_{(27.5)}$ from a one-parameter life table model. In the Carrier-Hobcraft tables, $\ell_{(27.5)}$= .6621 corresponds to $\ell_{(2)}$= .830 thus, given $\ell_{(27.5)}$= .6621, first estimates of $\ell_{(x)}$ in column 6 are generated from column 4.

(iii) Corresponding to the values of $\ell_{(x)}$ in column 6, β's in column 7 are estimated by equation:

$$\hat{\beta} = [Y_{(x)} - Y_{(2)}] / [Y_{s(x)} - Y_{s(2)}] \quad \ldots\ldots(4.1)$$

where $Y_{(x)}$ is the logit of $\ell_{(x)}$ and $Y_{s(x)}$ is the logit of the African Standard at age x .

(iv) By trial and error process β's are found to give new estimates of $\ell_{(x)}$ until there is a negligible difference between the old and the new estimates. Our example gives the second estimate of $\ell_{(27.5)}$= 0.679,

TABLE 4.7: Calculations of the Estimated Actual Ages using the Orphanhood Technique on the Proportions of Males and Females with Mothers Alive - Uganda 1969.

Age Group	Prop'rns with mothers Both sexes	Multiplying factors K	Median Age N	Mortality ratios $\frac{\ell_{(27.5+N)}}{\ell_{27.5}}$	Age of Mother X	Given $\ell_{27.5}$=.6621 $\hat{\beta}$ = .91423 1st.Est. ℓ_x	Implied β	4th.Est.of ℓ_x (Given $\ell_{27.5}$=.6862)
	1	2	3	4=1x2	5	6	7	8
5-9	.9710	1.0017	7.5	.9727	35	.6440	.8935	.6675
10-14	.9491	1.0048	12.5	.9537	40	.6314	.8214	.6544
15-19	.8974	1.0075	17.5	.9041	45	.5986	.8497	.6204
20-24	.8247	1.0110	22.5	.8338	50	.5521	.8779	.5722
25-29	.7327	1.0122	27.5	.7416	55	.4910	.9127	.5089
30-34	.6240	1.0125	32.5	.6318	60	.4183	.9434	.4335
35-39	.5254	.9999	37.5	.5253	65	.3478	.9385	.3605
40-44	.3926	.9707	42.5	.3811	70	.2523	.9632	.2615
45-49	.2980	.8822	47.5	.2629	75	.1741	.9395	.1804
50-54	.1814	.7315	52.5	.1327	80	.0879		.0911

Age Group	Smoothed ℓ_x	Smoothed Mortality Ratios $\frac{\ell_{27.5+N}}{\ell_{27.5}}$	Smoothed Prop'ns for both sexes	Observed Prop'rns by fem. with surv. mothers	Estim. Mid-ages for females	Observed Prop'rns by Males	Estim. Mid-Ages for Males
	9	10	11=10÷2	12	13	14	15
5-9	.6767	.9862	.9845	.9721	8.78	.9698	9.01
10-14	.6453	.9404	.9359	.9535	10.69	.9447	11.60
15-19	.6093	.8879	.8813	.9023	15.58	.8924	16.48
20-24	.5661	.8250	.8160	.8186	22.30	.8308	21.37
25-29	.5125	.7469	.7379	.7233	29.27	.7421	27.23
30-34	.4471	.6516	.6436	.6050	34.23	.6430	32.53
35-39	.3652	.5322	.5323	.4988	38.86	.5520	36.62
40-44	.2726	.3973	.4093	.3598	44.47	.4254	41.85
45-49	.1719	.2505	.2839	.2681	48.20	.3279	45.75
50-54	.0861	.1255	.1716	.1576	53.33	.2053	51.00

third estimate as 0.684 and the fourth estimate as 0.686. Column 8 shows the estimates of $\ell_{(35)}, \ell_{(40)}, \ldots\ldots \ell_{(80)}$ that are fitted by the orphanhood technique.

(v) By use of the equation:

$$\hat{Y}_{(x)} = \hat{\alpha} + \hat{\beta}\, Y_{s(x)} \qquad \ldots\ldots\ldots\ldots (4.2)$$

$\ell_{(35)}$ to $\ell_{(80)}$ in column 8 are smoothed to give column 9.

(vi) Finally, the reported proportions for each sex in columns 12 and 14 are linearly interpolated between the smoothed proportions in column 11 to yield the corresponding ages in columns 13 and 15.

The procedure is applied to data on mothers alive from Chad 1963-65, Kenya 1969 and Uganda 1969 and the results are shown in Table 4.8. We prefer to use maternal rather than paternal orphanhood data since the estimates of mortality from the former are more reliable. This happens because: (a) children are more likely to have accurate information for mothers, (b) the shorter reproductive period allows less scope for model biases and (c) there is better knowledge of female fertility pattern from observations.

4.5. Results from the simple and heavily graduated methods

Table 4.8 shows that female ages are over-stated at ages below 15 in Chad 1963-65, and below 20 in Uganda 1969 and Kenya 1969. Under-statements of female ages are shown in the reproductive period of 20 to 50. This finding from the graduated methods is consistent with the results from the simple technique shown in Table 4.5.

On the other hand, males are shown in Table 4.8 to have recorded higher ages throughout the indicated range in Kenya 1969 and Uganda 1969. Chad males in 1963-64 displayed under-reporting in age groups 20-24 and 40-44 but not otherwise. Fairly similar results for males were derived by

TABLE 4.8: Estimated Aged Derived from the Smoothed Proportions with Surviving Mothers

AGE GROUP	MEDIAN AGE	CHAD 1963-65 F	M	KENYA 1969 F	M	UGANDA 1969 F	M
10-14	12.5	10.5	10.6	11.2	11.7	10.7	11.6
15-19	17.5	17.7	16.8	15.8	16.3	15.6	16.5
20-24	22.5	23.6	22.8	21.9	21.2	22.3	21.4
25-29	27.5	29.4	27.3	27.8	26.3	29.3	27.2
30-34	32.5	35.5	32.2	33.8	31.8	34.2	32.5
35-39	37.5	38.6	35.8	38.1	36.3	38.9	36.6
40-44	42.5	44.6	42.9	43.6	41.3	44.5	41.8
45-49	47.5	48.7	45.7	48.0	46.1	48.2	45.8

the simple technique of Table 4.5 where over-statements appear in age groups above age 20. It is possible that this pattern is a reflection of a series of over-statements in all sections of male populations perhaps owing to the desire of men to attain the more dignified status accorded to elders in many African societies.

Other measures to display estimates of the deviations between reported and actual ages of males and females are given in Tables 4.9 and 4.10. It can be seen that males reported lower ages than females in Chad 1963-65 and from age 10 to 20 in the Kenya and Uganda censuses of 1969. In all the three countries males are shown to have stated higher ages than females from age 20 to 50. The gap between the reporting by males and females is small in young ages and becomes wider with advancing years.

It is worthy of note that the methods give contrasting results in some age groups. The results from the graduated methods (see Table 4.10) show that both sexes over-stated ages in the 10-19 age span in Kenya and Uganda. On the other hand, for the same instances, the simple technique yields results (see Table 4.9) which suggest that ages of males were under-stated while those of females over-stated. The difference is due to the failure of the simple relative approach to take account of the fact that under (or over) statements and under (or over) enumeration of both sexes may occur together in the same age groups.

4.6. Conclusion:

Two approaches have been used to examine and measure the differences between male and female age and coverage errors. The methods - 'simple' and 'graduated' - have been applied to orphanhood data from Chad's survey

TABLE 4.9: Deviations of the Estimated relative ages (in years) from the Reported Median Ages - Reported Proportions with Surviving Mothers.

Age Group	Median Age	CHAD 1963-65			KENYA 1969			UGANDA 1969		
		F	M	F-M	F	M	F-M	F	M	F-M
10-14	12.5	-0.2	+0.1	-0.3	-0.9	+1.4	-2.3	-1.4	+0.4	-1.8
15-19	17.5	+0.4	-0.4	+0.8	-0.3	+0.2	-0.5	-0.5	+0.3	-0.8
20-24	22.5	+0.4	-0.4	+0.8	+0.3	-0.6	+0.9	+0.3	-0.4	+0.7
25-29	27.5	+0.9	-1.1	+2.0	+0.5	-0.6	+1.1	+0.5	-0.5	1.0
30-34	32.5	+2.4	-1.6	+4.0	+1.1	-1.1	+2.2	+1.0	-0.9	+1.9
35-39	37.5	+1.1	-1.1	+2.2	+0.8	-1.3	+2.1	+1.0	-1.4	+2.4
40-44	42.5	+1.3	-0.6	+1.9	+1.2	-1.1	+2.3	+1.7	-1.2	+2.9
45-49	47.5	+1.9	-2.0	+3.9	+0.9	-1.0	+1.9	+1.3	-1.6	+2.9

TABLE 4.10: **Deviations of the Estimated Ages (in years) from the Reported Mid-Ages - Smoothed proportions with Surviving Mothers**

Age Group	CHAD 1963-65			KENYA 1969			UGANDA 1969		
	F	M	F-M	F	M	F-M	F	M	F-M
10-14	-2.0	-1.9	-0.1	-1.3	-0.8	-0.5	-1.8	-0.9	-0.9
15-19	+0.2	-0.9	+1.1	-1.7	-1.2	-0.5	-1.9	-1.0	-0.9
20-24	+1.1	+0.3	+0.8	-0.6	-1.3	+0.7	-0.2	-1.1	+0.9
25-29	+1.9	-0.2	+2.1	+0.3	-1.2	+1.5	+1.8	-0.3	+2.1
30-34	+3.0	-0.3	+3.3	+1.3	-0.7	+2.0	+1.7	0.0	+1.7
35-39	+1.1	-1.7	+2.8	+0.6	-1.2	+1.8	+1.4	-0.9	+2.3
40-44	+2.1	+0.4	+1.7	+1.1	-1.2	+2.3	+2.0	-0.7	+2.7
45-49	+1.2	-1.8	+3.0	+0.5	-1.4	+1.9	+0.7	-1.7	+2.4

of 1963-65 and the Kenya and Uganda censuses of 1969. The results from the two methods suggest that male populations over-state their ages while females under-state ages in the age groups above 20, and that the reverse is true below age 20.

The methods make three basic assumptions. The first is that the proportions for both sexes with surviving parents together are accurate on average. For the simple approach, the average is effectively taken separately for each age group. The assumption then means that when males reported higher ages, the females necessarily reported lower ages than the true values and that the deviations approximately cancelled. Such a proposition is not reasonable, since there is nothing to stop both sexes reporting ages with errors in the same direction. The technique is, therefore, a relative one which can only be expected to give differentials by sex of about the right size and not the separate absolute errors. In the smoothed method the 'averaging' is over both sex and age groups since a fairly rigid framework, the two-parameter logit mortality model is fitted. It is difficult to assess the possible biases, here, because this depends on the accuracy of the model and also the effects of time trends. Clearly a systematic component of error in the same direction for both sexes in all age groups would not be detected. Nevertheless, it can be inferred that components of error which are different by sex or age groups would appear. These may be the major effects.

The other assumptions are that the reporting of the proportions of parents alive are accurate or, less stringently, have the same relative error for both sexes; and that there is no differential survivorship of parents according to the sexes of their children. The first seems likely to hold in at least a reasonable number of surveys. The second cannot be checked by any available data but again it is implausible as a general result. The consistency of pattern in the estimates of deviations gives some support, therefore, for the belief that the assumptions are valid.

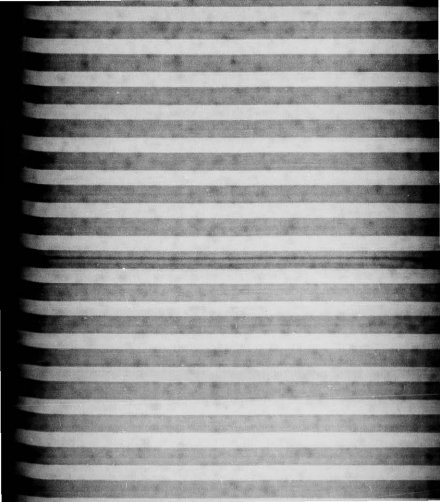
CHAPTER 5

THE DEMENY-SHORTER AND THREE-CENSUSES METHODS FOR CORRECTING AGE DATA

5.1 Introduction

For over two decades there have been many efforts to develop mortality model systems. The purpose of these systems has been to represent the age/sex mortality incidences of the actual populations in terms of fixed schedules, so that studies of various populations that lack complete data on mortality can be made by means of a small number of parameters of level and pattern which can be estimated from the available data. The first set and the best known of mortality models was produced by the U.N. Population Division in the mid-1950s. The U.N. Scheme was based on one parameter of level related to analysis of 158 life tables for some fifty countries and for the first half of the 20th. Century. Since the U.N. proposal, more flexible systems of mortality models have been evolved. In 1966, Ansley Coale and Paul Demeny produced a regional system with four sub-sets of varying patterns. However, as in the U.N. models, the Coale-Demeny system is determined by one-parameter of level but separately for each sub-set. The Ledermann and Breas scheme, published in 1969, gives six one-parameter sets and three two-parameter sets, the latter based on particular combinations of mortality measures. This system was related to a factor analysis of substantially the same life tables as were used in the construction of the U.N. system. The most flexible system of mortality models is the Carrier-Hobcraft (1971) set of tables, based on the Brass linear logit transformation and an African standard life table. The Carrier-Hobcraft system has two parameters, one which determines level and the other the relation between adult and childhood mortality.

By using the underlying patterns of mortality in these systems,



combined with a range of natural increases, stable population age distributions have also been constructed. It has been customary for many demographers to use the method of selecting a model stable age distribution, comparing it with the reported age distribution and attributing the differences to the age errors. This method, which is based on an unproven assumption that constant fertility and mortality conditions have prevailed in the reported populations for a considerable time, has been necessary for lack of data collected at more than one fairly well-conducted census in developing countries. However, recently the number of developing countries with two or more reasonable censuses has begun to increase rapidly and demographers have also begun to investigate possible methods of using age data from multiple censuses in order to measure and correct for age and coverage errors.

Probably the best known of the methods, using age data from two successive censuses, put forward so far is the Demeny-Shorter method (1968). When studying the Turkish censuses' data, Demeny and Shorter evolved the method by putting earlier ideas of Carrier and Farrag (1959) into a more general form. The mathematical formation of this method has been given in separate papers by Brass (1969) and Das Gupta (1975), who also made critical assessments. Das Gupta was not satisfied with the method because he claimed that it made an implicit assumption of identical age structures in the two successive censuses. To overcome this problem, Das Gupta proposed what he called 'a more general method' which yields almost the same results. Das Gupta's method is harder to evaluate and apply than the Demeny-Shorter method. On the other hand, Brass' appraisal of the Demeny-Shorter approach was supplemented by a proposal to use a third census to check the assumptions of the method.

The present and following chapters will be devoted to the exploration of new methods that may utilise age data reported at consecutive censuses in the same country. The present chapter has two basic parts. First, we shall examine some of the aspects of the Demeny-Shorter method by clarifying the algebraic notation and by applying it to the African and Turkish data. In the second part of the chapter, a method which makes use of age data from three successive censuses will be given and applied to data from the developing countries.

5.2. The Demeny-Shorter Method

The Demeny-Shorter method can be represented in the following notation:-

$A_i(1+\alpha_i)$ is the reported population in age group i for the first census,

$B_i(1+\alpha_i)$ is the reported population in age group i for the second census,

where A_i and B_i are the true populations in age group i for first and second censuses respectively, and $1+\alpha_i$ is the error component in group i. After correction for migration and territorial changes the assumptions made are:

(i) that the pattern of age mis-statements is systematic and therefore repeats itself from one census to the next, or more rigorously that the proportional error in an age group is constant: ie.

$$A_i = [A_i(1+\alpha_i)] / (1+\alpha_i) \quad \text{and} \quad B_i = [B_i(1+\alpha_i)] / (1+\alpha_i) \quad \ldots\ldots (5.1)$$

(ii) that the population is assumed to experience mortality according to a suitably selected mortality schedule, ie.

$$P_i = B_{i+1}/A_i \quad \ldots\ldots(5.2)$$

where P_i is the appropriate life table survivorship ratio in age group i. The choice of the suitable mortality level is done by a trial and error procedure, (see Coale and Demeny, 1967) using the life table of the model system which best describes the numbers of persons surviving from the first to the second date. The best level of mortality is decided by the agreement of the observed with the expected population numbers over 5, 10, ..., 45 years.

Application of these survivorship ratios to the reported numbers of the first census - $A_i(1+\alpha_i)$ - will give the true numbers for the following age group of the second census - $B_i(1+\alpha_i)$ - but with the error of the first one. There are then two unknown values for each i - B_i and α_i, but also two equations for each, except for B_1. Thus, the introduction of a third assumption as seen below is necessary for unique solutions for α_i and B_i (and hence A_i also).

(iii) The third assumption is that the total size of the population was enumerated correctly, ie.

$$\sum_i A_i\,(1+\alpha_i) = \sum_i A_i \quad \text{and} \quad \sum_i B_i(1+\alpha_i) = \sum_i B_i \qquad \ldots.(5.3)$$

Demeny and Shorter (1968) have given a simple procedure for arriving at the final correction factors and hence the corrected population age distributions.

The method as described above was successfully applied to Turkey, which has experienced a history punctuated by wars that from time to time resulted in unusually small birth cohorts. In the present study the method is extended in two ways. The first is to relax one of the assumptions underlying the method, namely that the coverage of the two successive censuses is the same. Secondly, the method is applied to several African populations, particularly those with a length of census interval different from 5 years. The purpose of the last application is to discover whether this method can work in countries other than Turkey.

5.2.1. Changing Census coverage

A test of how sensitive the Demeny-Shorter method is to changes in the census coverage is made by assuming:

(i) the same coverage of censuses in 1955 and 1960; see columns 2 and 5 of Table 5.1;

(ii) that the 1955 censuses had 3% omissions in every age group, that is 1.03 is a multiplier of each age group; see column 3 of Table 5.1;

(iii) that 3% over-enumeration in every age group occurred in the 1955 census, that is 1.03 is a divisor of each age group; see column 4 of Table 5.1.

The census coverage in 1960 is assumed to be unchanged from case (i) in (ii) and (iii).

The changes in (ii) and (iii) will affect the level of mortality chosen according to the trial and error procedure described. In (iii), this is because the change represents a reduction of numbers in each age group of the 1955 census. The reduction of numbers in turn means that the 1955 population needs higher survivorship ratios than in (i) if the expected numbers of 1960 are to agree with the reported 1960 population. Conversely, the change in (ii) requires lower survivorship ratios than in (i). Consequently, the survivorship ratios used for (i) come from South model level 16.3 corresponding to e^{o}_{5} = 63.5; for (ii) level 11.0 corresponding to e^{o}_{5} = 55.5 and for (iii) level 23.4 corresponding to e^{o}_{5} = 74.5 as seen in Table 5.2.

The correction factors obtained by varying the coverage of the 1955 census relative to that of 1960 are shown in Table 5.3. It is noteworthy that these final correction factors for the same age groups vary considerably, implying that the method is, to a noticeable extent, sensitive to the assumption of the same coverage at the two successive

TABLE 5.1: 1955 Census data adjusted for migration, territorial boundaries, omissions and over-enumeration, and 1960 census data for Turkey females

Age Group	REPORTED 1955 CENSUS Adjusted for Migration	1955 CENSUS Adjusted for Migration and 3% of Omissions	1955 CENSUS Adjusted for Migration and 3% of Over-Enumeration	REPORTED 1960 CENSUS Adjusted for Migration
0-4	1889	1946	1832	2079
5-9	1570	1617	1523	1928
10-14	1097	1130	1064	1489
15-19	1094	1127	1061	1059
20-24	1117	1151	1083	1128
25-29	1027	1058	996.2	1177
30-34	735.1	757.2	713.0	985.8
35-39	528.5	544.4	512.6	693.8
40-44	624.7	643.4	606.0	548.4
45-49	475.6	489.9	461.3	500.0
50-54	531.0	546.9	515.1	581.2
55-59	310.4	319.7	301.1	369.4
60-64	389.3	401.0	377.6	461.4
65-69	173.7	178.9	168.5	213.8
70-74	172.1	177.3	166.9	195.7
75+	159.3	164.1	154.5	182.1
	11893	12251.8	11535.6	13591

TABLE 5.2: Survivorship ratios of Mortality levels 11.0 (e_5^o=55.5) 16.3 (e_5^o=63.5) and 23.4 (e_5^o=74.5) of the South Model Life Tables

Age Group	Level 11.0 (e_5^o=55.5)	Level 16.3 (e_5^o=63.5)	Level 23.4 (e_5^o=74.5)
0-4	.91067	.9599	.99513
5-9	.97632	.9903	.99904
10-14	.97923	.9907	.99894
15-19	.97244	.9873	.99843
20-24	.96774	.9846	.99789
25-29	.96546	.9830	.99735
30-34	.96325	.9813	.99663
35-39	.96032	.9783	.99519
40-44	.95642	.9741	.99276
45-49	.94644	.9660	.98865
50-54	.92724	.9523	.98254
55-59	.89102	.9272	.97210
60-64	.83100	.8829	.95097
65-69	.74030	.8085	.90702
70-74	.61296	.6936	.82277
75+	.37780	.4414	.55154

TABLE 5.3: Correction Factors obtained by varying the Demeny-Shorter Assumption on census coverage of Turkish Female Population in 1955 and 1960.

Age Group	3% Omissions in 1955 Census South Level 11.0(e_5^o=55.5)	Same coverage for 1955 & 1960 Censuses South Level 16.3 (e_5^o=63.5)	3% Over-Enumeration in 1955 Census South Level 23.4 (e_5^o=74.5)
0-4	1.025	1.039	1.088
5-9	.942	.976	1.029
10-14	.998	1.020	1.052
15-19	1.043	1.047	1.056
20-24	1.013	1.002	.991
25-29	.958	.937	.910
30-34	.998	.960	.917
35-39	1.007	.998	.940
40-44	.959	.941	.875
45-49	1.181	1.146	1.052
50-54	.942	.906	.826
55-59	1.294	1.240	1.132
60-64	.798	.774	.718
65-69	1.244	1.244	1.207
70-74	.843	.893	.942
75+	.763	.954	1.335

censuses. However, it is important to remark that the deviations of the correction factors from unity for the same age groups are in the same direction, which suggests that a very similar pattern of age errors is obtained, irrespective of the changes in the census coverage. What Table 5.3 may be demonstrating is that changes in the enumeration coverage of two consecutive censuses are likely to lead to appreciable changes in the level of, but not the pattern of, the correction factors. This suggests that the effects of the chosen level of mortality on the results is not too large, and that a method which does not estimate it explicitly might be useful. Since the last few decades have witnessed a tremendous improvement in the procedures of data collection at censuses in developing countries, leading to better census coverage, a method that, unlike the Demeny-Shorter, does not depend on the assumption of constant coverage, is desirable.

5.2.2. Applying the Demeny-Shorter Method to the African situation

Further appraisal of the Demeny-Shorter method is made by the use of censuses of African countries that have a notably different demographic experience from Turkey. The censuses used are the 1960 and 1970 censuses of Ghana, the 1959 and 1969 censuses of Uganda and the 1962 and 1969 censuses of Kenya. Ghana, Kenya and Uganda are all black African countries that have radically different population characteristics from a Euro-Asian country such as Turkey. Firstly, in the present century these three countries, unlike Turkey, have not been directly involved in external wars, although they have experienced famines and epidemics from time to time. Secondly, the Turkish censuses since 1935 are believed to have had good coverage, while Uganda's 1959 census had clear deficiencies in some areas and the 1969 census was merely satisfactory; the 1962 Kenyan census relative to the one in 1969 left out about a fifth of the country's total area uncovered. Thirdly, unlike the Turkish case, there is quite inadequate information on migration to use for the adjustment of the Uganda and Ghana data. Fourthly, there is the difference in the length of census interval of these African countries, seven years for Kenya and ten years for Ghana and Uganda, compared with five year interval for all Turkish censuses since 1935. In this work, we examine the difference involved in applying the method to the census data at seven year and ten year intervals.

The calculation for Ghana and Uganda is similar to that used for Turkey, except that the ten year instead of five year life table survivorship ratios were used. For Kenya, seven year stationary populations, L_{0-6}, L_{7-13}, etc., were linearly interpolated from suitable five year stationary populations, L_{0-4}, L_{5-9}, etc. From the L_{0-6}, L_{7-13}, etc. seven year life table survivorship ratios were calculated and then used in the application of the Demeny-Shorter method to Kenyan data. The results of the application of the method to Ghana, Uganda and Kenya data are shown in Tables 5.4(a), 5.4(b) and 5.4(c), respectively.

Table 5.4(a) displays the correction factors and the corrected population distributions for Ghana in 1960 and 1970. The correction factors reflect a pattern of age errors quite unexpected in a tropical African country. The excess population implied in age 0-4 is incredibly large and contrary to other reports (such as Brass et al., 1968, p.45-49) which have disclosed underenumeration of children at censuses in Africa. However, some studies of the Ghana census of 1960 (e.g. Gaisie, 1973, p.233) show this phenomenon of over-enumerating children. Another unsatisfactory aspect of the age group 0-4 is the sex ratio implied by the corrected population. At both the 1960 and 1970 censuses, the ratios of age group 0-4 were reported at plausible estimates of 0.98 and 0.99 for 1960 and 1970 respectively, but after the Demeny-Shorter correction, the sex

TABLE 5.4(a): Results from Demeny-Shorter method for Ghana data of 1960 and 1970 censuses, Population in Thousands (000's)

	MALES					FEMALES				
Age Group	REPORTED POPULATION 1960	REPORTED POPULATION 1970	CORRECTION FACTORS	CORRECTED POPULATION 1960	CORRECTED POPULATION 1970	REPORTED POPULATION 1960	REPORTED POPULATION 1970	CORRECTION FACTORS	CORRECTED POPULATION 1960	CORRECTED POPULATION 1970
0-4	642.4	778.1	.876	562.3	681.1	654.3	785.1	.945	618.3	742.0
5-9	515.5	728.3	.876	451.2	637.5	503.0	721.9	.945	475.4	682.2
10-14	357.8	514.5	.964	344.6	495.5	323.5	488.2	1.121	362.0	547.3
15-19	275.5	399.0	1.064	293.1	424.4	265.5	379.0	1.182	313.8	447.9
20-24	268.3	305.6	1.056	283.4	322.7	322.6	375.5	.904	291.7	339.6
25-29	278.6	289.9	.928	258.5	269.0	306.3	341.5	.846	258.9	288.7
30-34	242.5	264.6	.978	237.1	257.8	245.9	296.9	.896	220.4	266.1
35-39	198.2	221.4	1.056	209.2	233.7	179.2	216.9	1.083	194.0	234.8
40-44	165.9	174.4	1.215	201.4	211.7	145.6	175.6	1.124	163.7	197.4
45-49	122.8	144.0	1.270	155.8	182.8	95.59	128.1	1.327	126.9	170.0
50-54	96.78	119.7	1.420	137.3	169.8	81.72	111.8	1.239	101.2	138.4
55-59	59.31	76.47	1.627	96.46	124.4	48.41	66.04	1.542	74.64	101.8
60-64	63.47	75.30	1.340	85.01	100.8	54.57	71.08	1.051	57.39	74.73
65-69	32.38	47.73	1.310	42.39	62.48	28.58	46.49	1.046	29.92	48.65
70-74	29.80	42.00	1.088	32.41	45.69	26.73	40.39	.769	20.53	31.06
75+	50.91	67.78	.276	14.02	18.66	45.08	67.11	.196	8.84	13.15
TOTAL	3,400	4,248	-	3404.19	4238.03	3,327	4,312	-	3317.62	4323.70

ratios dropped to unbelievable values of 0.91 for 1960 and 0.92 for 1970. Although it is known that more male than female infants and children die, the sex ratio is not expected to drop so much below unity in the first five year age group. Thus, it seems certain that the correction factor for males in the 0-4 age group is under-estimated. A further remark to be made on the correction factors is that whilst they deviate widely from unity, implying large errors in the censuses of 1960 and 1970, there is no markedly systematic error pattern, contrary to what is implied by the analysis of digit preference in Chapter 2.

The corrected age structures for 1960 and 1970, compared with the reported distributions, reflect a fairly regular trend of real fluctuations in the recent past. However, care must be taken in accepting this interpretation since the original data were not adjusted for the migration effects arising from the Ghanaian Government's decision to expel foreigners during the period between the censuses. It is possible, for instance, that the decreasing effect of the expulsion on the 1970 census data had the effect of reducing the level of mortality chosen, but the selected levels of mortality from the Carrier-Hobcraft tables are 45 consistent with $e_o^o = 42.50$ for males and 46.5 consistent with $e_o^o = 43.25$ for females. These are quite acceptable for African populations and, as shown before, the effect of variation in the level of mortality on the results does not change the pattern.

In addition, the correction factors and corrected population distributions for Uganda in 1959[1] and 1969 are shown in Table 5.4(b). The correction factors for Uganda show smaller deviations from unity than those for Ghana, which is indicative of a better quality of age data in the former country. This result is surprising because it is believed that the Uganda 1959 census was much more poorly conducted than the

1. It must be pointed out here that the Uganda 1959 Census five year age groupsused in the application were interpolated, using the "Oblique Axis Ogive" method, from the reported broad age groups- under 1, 1-5, 6-15,

TABLE 5.4(b): Results from the Demeny-Shorter method for data of Uganda 1959 and 1969 Censuses. Population in Thousands (000's)

Age Group	Males					Females				
	REPORTED POP'N		CORRECTION FACTORS	CORRECTED POP'N		REPORTED POP'N		CORRECTION FACTORS	CORRECTED POP'N	
	1959	1969		1959	1969	1959	1969		1959	1969
0-4	561	904	1.039	583	939	558	924	1.067	595	986
5-9	443	731	1.039	460	759	427	729	1.067	456	778
10-14	344	568	.995	343	565	337	517	1.069	360	553
15-19	282	411	1.102	311	453	294	410	1.070	315	439
20-24	259	335	1.004	260	337	293	378	.914	268	346
25-29	258	349	.870	224	303	281	377	.790	222	298
30-34	232	302	.839	194	253	242	297	.849	205	252
35-39	204	256	.852	173	218	204	236	.881	179	208
40-44	177	197	.955	169	188	168	190	1.002	169	190
45-49	149	168	.991	148	166	130	149	1.100	143	164
50-54	114	148	1.078	123	160	94	144	1.038	97	149
55-59	80	97	1.404	112	136	70	81	1.502	105	122
60-64	60	98	1.111	66	109	52	91	.851	44	78
65-69	35	62	1.494	52	92	29	49	1.526	44	75
70-74	22	54	.896	20	49	17	46	.575	10	27
75+	18	89	.346	6	31	15	63	.327	5	20
TOTAL	3237	4770	-	3244	4758	3213	4687	-	3217	4685

1969 census, while the quality gap between the 1960 and 1970 Ghana census data is believed not to have been wide. Furthermore, Table 5.4(b) displays patterns of the correction factors and corrected population for Uganda which appear credible. As shown in the Table, the above unity estimates in age group 0-4 suggest correction for underestimating young children, probably caused by omissions at censuses. The relative excesses displayed in age range 20-39 are largely counter-balanced by the deficits shown in age groups 15-19 and 40-59. Also evident from the Table is systematic mis-reporting at advanced ages, perhaps owing to the more pronounced distorting effect of age heaping on advanced ages (as already discussed in Chapter 2). The corrected age distributions for 1959 and 1969 show that population in higher age groups is smaller than in lower groups which, as expected, suggests no evidence of irregular birth cohorts in the recent past; but surprisingly, the 1969 structure does not show the effect of large immigration in the early 1960's, perhaps because most of the immigrants were political refugees who tended to come in families of all age groups.

Furthermore, the appraisal of the Demeny-Shorter method is made by applying it to the Kenyan data from censuses that were seven years apart. The correction factors and corrected population age distributions for 1962 and 1969 are in Table 5.4(c). Despite the unusual census interval used, the results for the age groups up to age 35 look fairly plausible, in that the correction factors are not very far from unity and the corrected age structures are regular. However, it is worth noting that the sex ratios - 1.06 for 1962, and 1.10 for 1969 of the corrected population in age group 0-6 are too high, considering that the sex ratio at birth in tropical Africa is about 1.03 to 1.05 and decreases with age at young ages due to more male than female infants and children

TABLE 5.4(c): **Results from the Demeny-Shorter method for data of Kenya 1962 and 1969 censuses. Population in Thousands (000's)**

Age Group	REPORTED POP'N		CORRECTION FACTORS	CORRECTED POP'N		REPORTED POP'N		CORRECTION FACTORS	CORRECTED POP'N	
	1962	1969		1962	1969	1962	1969		1962	1969
0-6	1003	1463	1.067	1070	1560	1027	1439	.988	1014	1422
7-13	821.9	1096	.963	791.9	1056	750.9	1044	.943	707.9	984.1
14-20	596.6	814.8	.965	575.7	786.1	628.3	800.0	.927	582.7	696.4
21-27	354.9	520.3	1.096	388.8	569.9	469.9	566.6	1.006	472.5	569.7
28-34	336.7	414.0	.928	312.6	384.4	431.5	459.2	1.004	433.2	461.0
35-41	307.0	357.5	.860	264.0	307.5	327.1	377.1	1.109	362.6	418.1
42-48	196.4	233.6	1.110	217.9	259.3	167.6	226.3	1.543	258.5	349.0
49-55	157.5	196.8	1.073	169.1	211.3	136.8	196.8	1.233	168.6	242.7
56-62	114.7	154.2	1.039	119.2	160.2	94.56	143.0	1.063	100.5	152.0
53-69	54.12	100.6	1.082	58.54	108.8	43.88	86.57	.985	43.22	85.26
70-76	53.31	65.98	.688	36.68	45.40	40.99	60.96	.477	19.54	29.06
77+	53.11	65.50	.718	38.11	47.00	37.82	60.66	.376	14.31	22.96
TOTAL	4053	5482	-	4043	5496	4156	5460	-	4178	5432

dying. The reason for the too high ratios is that the correction factor for males (1.067) is over-estimated or the correction factor for females (.988) is under-estimated. A further unsatisfactory feature of the estimates in Table 5.4(c) is the violently fluctuating pattern of the correction factors after age 35, especially for females. The estimated correction factors for age 42 to 62 are too high and thus suggest incredibly large underenumeration in these ages. On the other hand, the estimates for ages above 62 are too low, implying too large overenumerations. A final problem with the results in Table 5.4(c) is to convert the seven year correction factors and age distributions into the customary five-year age groups for conventional analysis.

Lastly, it is important to note the levels of mortality used for Uganda and Kenya. Because of the poor coverage at earlier censuses of Uganda and Kenya, the levels of mortality located by the projection method (already described) for the two countries are all higher (Uganda males - level 90: e_o^o = 65.80; females - level 65: e_o^o = 52.50; Kenya males - level 101.3: e_o^o = 70.59; females - level 80.4: e_o^o = 60.62 of the Carrier-Hobcraft tables) than levels consistent with the estimates of early child mortality for the intercensus period of these countries (males - level 40: e_o^o = 40.00; females - level 45: e_o^o = 42.50). To compare and check the above results, the survivorship ratios corresponding to the mortality levels 40 and 45 are adopted in the application of Demeny-Shorter method to data from the Uganda 1959 and 1969, Kenya 1962 and 1969 censuses. The resulting correction factors are shown in Tables 5.5(a) and 5.5(b). A comparison of these correction factors with those from higher levels of mortality shows a striking resemblance in pattern, though the levels vary widely. This suggests, as in the case of Turkey, where coverage was considered to vary, that the application of the Demeny-Shorter

TABLE 5.5(a): Correction Factors resulting from the use of different Carrier-Hobcraft levels of Mortality for Uganda, 1959 and 1969 Censuses

Age Group	MALES		FEMALES	
	e_0^o=40.00 Level 40	e_0^o=65.80 Level 90	e_0^o=42.50 Level 45	e_0^o=52.50 Level 65
0-4	1.199	1.039	1.134	1.067
5-9	1.199	1.039	1.134	1.067
10-14	1.027	.995	1.079	1.069
15-19	1.207	1.102	1.111	1.070
20-24	.980	1.004	.900	.914
25-29	.887	.870	.795	.790
30-34	.758	.839	.808	.849
35-39	.801	.852	.856	.881
40-44	.789	.955	.919	1.002
45-49	.840	.991	1.024	1.100
50-54	.785	1.078	.904	1.038
55-59	1.015	1.404	1.312	1.502
60-64	.659	1.111	.686	.851
65-69	.831	1.494	1.214	1.526
70-74	.385	.896	.417	.575
75+	.135	.346	.231	.327

TABLE 5.5(b): Correction Factors resulting from the use of different Carrier-Hobcraft levels of Mortality for Kenya, 1962 and 1969 Censuses

Age Group	MALES e^o_o= 40.00 Level 40	MALES e^o_o=70.59 Level 101.3	FEMALES e^o_o=42.50 Level 45	FEMALES e^o_o=52.50 Level 65
0-6	1.254	1.067	1.137	.988
7-13	1.042	.963	1.027	.943
14-20	1.001	.965	.923	.927
21-27	1.078	1.096	.966	1.006
28-34	.864	.928	.930	1.004
35-41	.743	.860	.979	1.109
42-48	.890	1.110	1.297	1.543
49-55	.771	1.073	.968	1.233
56-62	.638	1.039	.758	1.063
63-69	.542	1.082	.625	.985
70-76	.246	.688	.255	.477
77+	.109	.718	.091	.376

method can produce a consistent pattern of correction factors, even if the coverage errors and migration effects are not adjusted for in the original data, and regardless of the level of mortality chosen.

5.3. A Three-Censuses Method

As reported above (section 5.2.1) the Demeny-Shorter method is inadequate where procedures of age collection, and therefore errors, have been changing greatly. Brass (1969) has suggested an extension which uses age data from three censuses, but it is essentially an averaging of two successive two census techniques and only applicable when error changes are systematic and small. A more flexible method which takes account of changes in the age reporting and coverage errors and which conveniently uses information in three censuses held at equal intervals is considered in this second part of the chapter. The three censuses method is based on two of the three assumptions made by Demeny-Shorter method, namely that the population can be assumed to have experienced mortality according to a suitably chosen model mortality schedule; and that the total size of the population was enumerated correctly. The assumption of the Demeny-Shorter method left out is that of size of age errors being constant at successive censuses. It is replaced by an assumption of regularity of change in error, that is, that a geometric mean relationship holds between error components of the same age group in the three censuses.

5.3.1. The Method

Let A, B and C be three successive censuses such that the respective enumerated data are:-

$$A_1(1+\alpha_1),\ A_2(1+\alpha_2),\ldots\ldots\ldots\ldots\ldots,\ A_{15}(1+\alpha_{15});$$
$$B_1(1+\beta_1),\ B_2(1+\beta_2),\ldots\ldots\ldots\ldots\ldots,\ B_{15}(1+\beta_{15});$$
$$C_1(1+\gamma_1),\ C_2(1+\gamma_2),\ldots\ldots\ldots\ldots\ldots,\ C_{15}(1+\gamma_{15}) \qquad \ldots.(5.4)$$

where $(1+\alpha_i)$, $(1+\beta_i)$ and $(1+\gamma_i)$ are error components (or error factors) and A_i, B_i and C_i are the true populations in age group i (i = 1, 2,...,15). The reported survivorship ratios, ie., S_i between censuses A and B and S_i^* between censuses B and C can be expressed as follows:-

$$S_1 = P_1 \frac{1+\beta_2}{1+\alpha_1}$$

$$S_2 = P_2 \frac{1+\beta_3}{1+\alpha_2}$$

$$\vdots$$

$$S_{14} = P_{14} \frac{1+\beta_{15}}{1+\alpha_{14}} \qquad \text{.........(5.5)}$$

and

$$S_1^* = P_1^* \frac{1+\gamma_2}{1+\beta_1}$$

$$S_2^* = P_2^* \frac{1+\gamma_3}{1+\beta_2}$$

$$\vdots$$

$$S_{14}^* = P_{14}^* \frac{1+\gamma_{15}}{1+\beta_{14}} \qquad \text{.........(5.6)}$$

where P_i and P_i^* are the suitable life table survivorship ratios. They are assumed known so that the $(1+\beta_2)/(1+\alpha_1)$, $(1+\beta_3)/(1+\alpha_2)$,..........., $(1+\beta_{15})/(1+\alpha_{14})$ and $(1+\gamma_2)/(1+\beta_1)$, $(1+\gamma_3)/(1+\beta_2)$,..........,$(1+\gamma_{15})/(1+\beta_{14})$ can be found.

Introduce notations r_i and r_i^* such that

$$r_1 = \frac{1+\beta_2}{1+\alpha_1}$$

$$r_2 = \frac{1+\beta_3}{1+\alpha_2}$$

$$\vdots$$

$$r_{14} = \frac{1+\beta_{15}}{1+\alpha_{14}} \qquad \text{.........(5.7)}$$

and

$$r_1^* = \frac{1+\gamma_2}{1+\beta_1}$$

$$r_2^* = \frac{1+\gamma_3}{1+\beta_2}$$

$$\vdots \qquad \vdots$$

$$r_{14}^* = \frac{1+\gamma_{15}}{1+\beta_{14}} \qquad \text{.........(5.8)}$$

Next, assume a geometric mean relationship:

$$(1+\alpha_2)(1+\gamma_2) = (1+\beta_2)^2$$

$$(1+\alpha_3)(1+\gamma_3) = (1+\beta_3)^2$$

$$\vdots \qquad \vdots$$

$$(1+\alpha_{15})(1+\gamma_{15}) = (1+\beta_{15})^2 \qquad \text{.........(5.9)}$$

to hold between error components of the same age group in the three censuses. In practice this assumption differs little from a linear change in error proportion, but the geometric expression simplifies the algebra.

We now consider the ratios of errors:

$$\frac{r_1^2}{r_1^*} = \frac{(1+\beta_2)^2}{(1+\alpha_1)^2} \cdot \frac{(1+\beta_1)}{(1+\gamma_2)}$$

$$= \frac{(1+\beta_1)}{(1+\alpha_1)} \cdot \frac{(1+\alpha_2)}{(1+\alpha_1)} \qquad \text{........(5.10)}$$

$$= k.\ \frac{1+\alpha_2}{1+\alpha_1} \qquad \text{where } k = \frac{1+\beta_1}{1+\alpha_1}$$

$$\frac{r_1 . r_2^2}{r_1^* . r_2^*} = \frac{1+\beta_1}{1+\alpha_1} \cdot \frac{1+\alpha_3}{1+\alpha_2}$$

$$= k.\ \frac{1+\alpha_3}{1+\alpha_2} \qquad \text{........(5.11)}$$

- - - - - - - - - -

$$\frac{r_1.r_2.\ r_3 \ldots\ldots\ r_{15}{}^2}{r_1^*.r_2^*.\ r_3^* \ldots\ldots\ r_{15}^*} = \frac{1+\beta_1}{1+\alpha_1} \cdot \frac{1+\alpha_{15}}{1+\alpha_{14}}$$

$$= k.\frac{1+\alpha_{15}}{1+\alpha_{14}} \qquad \ldots\ldots\ldots(5.12)$$

Steps of calculations of error components estimates are:

(i) By guessing k (eg. k=1 , implying the same proportion of error in all censuses), we calculate:

$$\frac{1+\alpha_2}{1+\alpha_1}\ ,\quad \frac{1+\alpha_3}{1+\alpha_2}\ ,\quad \frac{1+\alpha_4}{1+\alpha_3} \quad \text{etc..}$$

(ii) Successive multiplication of the ratios in (i) gives:

$$\frac{1+\alpha_2}{1+\alpha_1}\ ,\quad \frac{1+\alpha_3}{1+\alpha_1}\ ,\quad \frac{1+\alpha_4}{1+\alpha_1} \quad \text{etc..}$$

(iii) Using the identities:

$$\frac{A_i(1+\alpha_i)}{(1+\alpha_i)} \ .\ (1+\alpha_1) = A_i(1+\alpha_1)$$

and $\Sigma A_i \quad = \Sigma A_i(1+\alpha_i)$

we obtain $1+\alpha_1$ and hence $1+\alpha_2$, $1+\alpha_3$ etc..

(iv) From $1+\beta_2 = r_1(1+\alpha_1)$ etc., we find the values of $1+\beta_2$, $1+\beta_3$, $1+\beta_4$ etc., and thus from Census B we get $1+\beta_1$.

(v) $\frac{1+\beta_1}{1+\alpha_1}$ gives a new value of k which is used to repeat the calculations until the new k is approximately the same as the old k .

(vi) The values of $(1+\gamma_i)$'s are derived from the relationship

$$1+\gamma_i = \frac{(1+\beta_i)^2}{1+\alpha_i}$$

5.3.2. Application and Results

(a) Using five year interval census data:

An illustrative example of the calculations involved in the above method is shown in Table 5.6 as applied to Turkish female data of 1955, 1960 and 1965 censuses. Factors of under-enumeration and over-enumeration (henceforth to be referred to as factors of age and coverage errors) are shown in columns 17, 20 and 23 for 1955, 1960 and 1965 censuses, respectively. The estimated and enumerated populations for the three censuses are shown in columns 15, 18, 21, 22, 24 and 25 of the Table. The results of the application of the method to all the quinquennial censuses of Turkey between 1935 and 1970 are shown in Tables 5.7, 5.8, 5.9 and 5.10.

Tables 5.7 and 5.8 show factors of age and coverage errors for the Turkish males and females in censuses held between 1935 and 1970. It is important to notice that the censuses of 1945, 1950 1955 and 1960 show three estimates for the same age groups, because three different but successive ten year periods each covering three censuses are used. For instance, estimates for the year 1950 are $1+\alpha_i$'s from 1950-55-60 period, $1+\beta_i$'s from 1945-50-55 period and $1+\gamma_i$'s from 1940-45-50 period. In addition, two sets of estimates are given for each end of the census years 1940 and 1965 while 1935 and 1970 display one set each, for the same reason. These sets of estimates of factors of age and coverage errors are put together for comparison purposes.

It is clear from the comparison of the different sets of the same year, that the estimates of factors of age and coverage errors for the three or four youngest five year age groups display a remarkable degree of agreement. However, other age and coverage error components are not close - some of them are in different directions. The reason for the

TABLE 5.6: An Illustration of the Computations involved in the Three-census Method: Applied to Turkey Females 1955, 1960 and 1965 (in 000's)

AGE GROUP	i	Enumerated Populations $A_i(1+\alpha_i)$ 1955	$B_i(1+\beta_i)$ 1960	$C_i(1+\lambda_i)$ 1965	Survivorship Rates, Lifetable P_i 1955-60	P^*_i 1960-65	Observed S_i 1955-60	S^*_i 1960-65	$r_i = S_i/P_i$ 1955-60	$r_i = S_i/P^*_i$ 1960-65	CHAINED r_i's 1955-60	CHAINED r^*_i 1960-65	$k.\frac{1+\alpha_{i+1}}{1+\alpha_i}$
		1	2	3	4	5	6	7	8	9	10	11	12
0-4	1	1889.0	2079.0	2283.0	.95487	.95445	1.02065	1.07744	1.06332	1.12892	1.06332	1.12892	1.00153
5-9	2	1570.0	1928.0	2240.0	.99026	.98872	.94841	.93776	.95774	.94846	1.01838	1.07073	.91091
10-14	3	1097.0	1469.0	1808.0	.99072	.98944	.96536	.92210	.97440	.93194	.99231	.99786	.96899
15-19	4	1094.0	1059.0	1373.0	.98727	.98561	1.03168	1.10009	1.04437	1.11616	1.03634	1.11376	.97178
20-24	5	1117.0	1128.0	1165.0	.98461	.98273	1.05372	1.04787	1.07019	1.06632	1.10908	1.18763	.99940
25-29	6	1027.0	1177.0	1182.0	.98300	.98102	.95988	.97366	.97648	.99252	1.08300	1.17874	.89717
30-34	7	735.1	985.8	1146.0	.99122	.97914	.94382	.95202	.96188	.97230	1.04171	1.14609	.87428
35-39	8	528.5	693.8	938.5	.97827	.97616	1.03765	.96671	1.06070	.99031	1.10495	1.13499	1.03263
40-44	9	624.7	546.4	670.7	.97405	.97194	.80038	.76556	.82171	.80824	.90794	.91734	.81329
45-49	10	475.6	500.0	430.8	.96601	.96362	1.22204	1.18240	1.26503	1.22704	1.14858	1.12562	1.29084
50-54	11	531.0	581.2	591.2	.95221	.94914	.69567	.72798	.73058	.76699	.83913	.86333	.71011
55-59	12	310.4	369.4	423.1	.92711	.92265	1.46647	1.38305	1.60334	1.49900	1.34541	1.29413	1.66687
60-64	13	389.3	461.4	510.9	.88274	.87641	.54919	.59353	.62214	.67734	.83704	.87657	.59409
65-69	14	173.7	213.8	273.9	.80843	.79983	1.12666	1.05987	1.39363	1.32512	1.16653	1.16156	1.39959
70-74	15	172.1	195.7	226.6	.69349	.68318	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
TOTAL		11734.4	13409.5	15262.7									

AGE GROUP	i	$\frac{1+\alpha_{i+1}}{1+\alpha_i}$	$\frac{1+\alpha_i}{1+\alpha_1}$	$A_i(1+\alpha_i)$ 1955	$A_i(1+\alpha_1)$	$1+\alpha_i$	A_i Estim.1955	r_i	$1+\beta_i$	Enum. 1960	B_i Estim.1960	$1+\gamma_i$	Enum. 1965	C_i Estim.1965
		13	14	15	16	17	18	19	20	21	22	23	24	25
0-4	1	1.04142	1.00000	1889.0	1889.0	1.00664	1876.5	1.06332	.96808	2079.0	2147.6	.93099	2283.0	2452.2
5-9	2	.94719	1.04142	1570.0	1507.6	1.04834	1497.6	.95774	1.07038	1928.0	1801.2	1.09288	2240.0	2049.6
10-14	3	1.00759	.98643	1097.0	1112.1	.99298	1104.8	.97440	1.00403	1469.0	1483.0	1.01521	1808.0	1750.9
15-19	4	1.01049	.99391	1094.0	1100.7	1.00052	1093.4	1.04437	.96756	1059.0	1094.5	.93570	1373.0	1467.4
20-24	5	1.03922	1.00434	1117.0	1112.2	1.01101	1104.8	1.07019	1.04491	1128.0	1079.5	1.07995	1165.0	1078.8
25-29	6	.93291	1.04373	1027.0	984.0	1.05066	977.5	.97648	1.08197	1177.0	1087.8	1.11421	1182.0	1060.8
30-34	7	.90911	.97370	735.1	755.0	.98017	756.0	.96188	1.02595	985.8	960.9	1.07388	1146.0	1067.2
35-39	8	1.07376	.88520	528.5	597.0	.89108	593.1	1.06070	.94280	693.8	735.9	.99753	938.5	940.8
40-44	9	.84569	.95049	624.7	657.2	.95680	652.9	.82171	.94517	546.4	580.2	.93367	670.7	718.3
45-49	10	1.34227	.80382	475.6	591.7	.80916	587.8	1.26503	.78621	500.0	636.0	.75392	430.8	563.9
50-54	11	.73839	1.07894	531.0	492.2	1.08611	488.9	.73058	1.02361	581.2	567.8	.96472	591.2	612.8
55-59	12	1.73327	.79668	310.4	389.6	.80197	387.0	1.60334	.79349	369.4	465.5	.78510	423.1	538.9
60-64	13	.61775	1.38087	389.3	281.9	1.39004	280.1	.62214	1.28584	461.4	358.8	1.16964	510.9	429.5
65-69	14	1.45535	.85304	173.7	203.6	.85870	202.3	1.39363	.86480	213.8	247.2	.87095	273.9	314.5
70-74	15	0.00000	1.24147	172.1	138.6	1.24971	137.7	0.00000	1.19672	195.7	163.5	1.14597	226.6	197.7
TOTAL				11734.4	11612.3		11734.4			13409.5	13409.5		15262.7	15273.5

ORIGINAL VALUE OF K = .9616890000 ESTIMATED VALUE OF K = .9616886440 discrepant estimates at older ages may be that causes of age data distortion other than age misreporting and coverage errors are operating. The causes may include inadequate allowance for gross migration and wrong choice of mortality level due to overall coverage errors.

Although the estimates of error factors in Tables 5.7 and 5.8 are expressed in relative terms, it is possible to compare the estimates of different age groups in the same set of estimates. Larger estimates, especially above unity, indicate over-enumeration or over-statement of the age group relative to the neighbouring groups; and conversely, smaller estimates, particularly below unity, represent under-enumeration or under-statements of the age group relative to the adjacent groups. Thus, as can be seen from these Tables, it is reassuring to note that in almost all censuses the estimates show underenumeration of the age group 0-4 relative to age group 5-9. This result is scarcely unexpected in a country where vital registration is incomplete and sociocultural taboos may not allow parents to disclose information about their children to census enumerators. Also indicated is a tendency to errors of over-enumeration at old ages (over 50), hardly an astonishing finding, since men in some developing societies prefer to be reported older as a token of respect or veneration. Another notable feature common to most estimates in Tables 5.7 and 5.8 is that the younger ages show closer agreement between the adjacent estimates ($1+\alpha_i$, $1+\beta_i$, $1+\gamma_i$) of the same group for the same census year than older ages. The possible cause of this result is the effects of the assumptions of the method on the estimates. The method's dependency on cumulation of equation from the earliest ages upwards assumes that errors in the earlier age groups cancel out, but in some instances the errors may become progressively greater in their effects with older ages. Also, the moderate deviations from the assumption that $1+\alpha_i$, $1+\beta_i$ and $1+\gamma_i$ are

TABLE 5.7: Estimated factors of Age and Coverage Errors in Male Populations of Turkey 1935-70

Age Group	1935 $1+\alpha_i$	1940 $1+\alpha_i$	1940 $1+\beta_i$	1945 $1+\alpha_i$	1945 $1+\beta_i$	1945 $1+\gamma_i$	1950 $1+\alpha_i$	1950 $1+\beta_i$	1950 $1+\gamma_i$
0-4	.907	.998	.821	.883	.969	.742	.924	.903	.940
5-9	1.026	1.189	.986	1.028	1.153	.948	1.040	1.019	1.118
10-14	1.105	1.124	1.013	.993	1.120	.929	.988	.995	1.116
15-19	1.263	.925	1.079	1.024	1.022	.921	.965	1.002	1.129
20-24	1.335	.859	1.199	1.026	.924	1.077	.939	.996	.995
25-29	1.314	.801	1.242	.978	.841	1.174	.953	.980	.883
30-34	1.260	.872	1.332	1.171	.908	1.408	1.000	1.098	.945
35-39	1.217	.934	1.302	1.181	.912	1.392	1.012	1.147	.890
40-44	1.125	.979	1.202	1.108	.922	1.285	1.013	1.126	.869
45-49	1.071	.935	1.099	1.054	.918	1.128	1.057	1.084	.902
50-54	.870	.978	.996	1.054	.970	1.141	1.169	1.105	.962
55-59	.589	1.007	.738	.783	.907	.923	1.118	.887	.816
60-64	.611	1.623	.793	.973	1.405	1.028	1.549	1.050	1.216
65-69	.339	1.270	.433	.606	1.133	.553	1.253	.700	1.010
70-74	.290	2.006	.396	.566	1.590	.542	1.516	.674	1.260

Age Group	1955 $1+\alpha_i$	1955 $1+\beta_i$	1955 $1+\gamma_i$	1960 $1+\alpha_i$	1960 $1+\beta_i$	1960 $1+\gamma_i$	1965 $1+\beta_i$	1965 $1+\gamma_i$	1970 $1+\gamma_i$
0-4	1.010	.954	.923	.955	.976	.986	.983	.944	1.011
5-9	1.046	1.034	1.011	1.058	1.087	1.027	1.106	1.131	1.156
10-14	1.031	1.016	.996	.991	1.057	1.045	1.055	1.085	1.123
15-19	1.013	.974	.980	.857	.997	.983	.919	.981	.986
20-24	.929	.932	.967	.795	.962	.926	.856	.997	.922
25-29	.863	.926	.983	.752	.898	.901	.772	.933	.792
30-34	.934	1.002	1.030	.883	.935	1.004	.784	.936	.696
35-39	.944	1.001	1.114	1.049	.948	1.017	.898	.951	.770
40-44	.970	1.010	1.145	1.222	.937	1.007	1.002	.905	.821
45-49	.963	1.002	1.115	1.331	.913	.950	1.128	.865	.956
50-54	1.123	1.129	1.158	1.649	1.048	1.091	1.427	.979	1.235
55-59	1.082	1.063	1.005	1.682	1.004	1.010	1.465	.931	1.276
60-64	1.484	1.429	1.133	2.353	1.342	1.318	2.033	1.213	1.757
65-69	1.276	1.192	.808	2.101	1.177	1.134	1.906	1.087	1.729
70-74	1.556	1.437	.802	2.644	1.459	1.363	2.440	1.368	2.252

TABLE 5.8: Estimated Factors of Age and Coverage Errors in Female Populations of Turkey, 1935-70

Age Group	1935 $1+\alpha_i$	1940 $1+\alpha_i$	1940 $1+\beta_i$	1945 $1+\alpha_i$	1945 $1+\beta_i$	1945 $1+\gamma_i$	1950 $1+\alpha_i$	1950 $1+\beta_i$	1950 $1+\gamma_i$
0-4	1.025	.872	.937	.844	.854	.857	.951	.973	.837
5-9	1.156	1.078	1.134	.905	1.036	1.113	1.135	.984	.996
10-14	1.054	.991	1.031	.746	.958	1.008	1.022	.809	.926
15-19	.985	.916	.996	.771	.967	1.006	1.090	.795	1.021
20-24	1.106	.872	1.070	.862	.953	1.036	1.112	.830	1.042
25-29	1.154	1.133	1.250	1.065	1.104	1.354	1.200	.972	1.075
30-34	1.053	1.304	1.178	1.159	1.195	1.318	1.220	1.056	1.095
35-39	.910	1.184	.961	1.117	1.125	1.016	1.075	1.036	1.068
40-44	.952	1.279	.980	1.315	1.244	1.010	1.106	1.202	1.210
45-49	.702	.922	.726	1.234	.980	.751	.872	1.101	1.042
50-54	.968	1.208	.977	1.962	1.251	.986	1.009	1.631	1.296
55-59	.604	.628	.591	1.442	.715	.578	.622	1.276	.814
60-64	1.172	1.094	1.153	3.446	1.204	1.133	.914	2.675	1.326
65-69	.540	.467	.560	2.320	.551	.581	.414	1.862	.651
70-74	.925	.849	.970	4.766	.847	1.016	.491	3.559	.846

Age Group	1955 $1+\alpha_i$	1955 $1+\beta_i$	1955 $1+\gamma_i$	1960 $1+\alpha_i$	1960 $1+\beta_i$	1960 $1+\gamma_i$	1965 $1+\beta_i$	1965 $1+\gamma_i$	1970 $1+\gamma_i$
0-4	1.007	.905	1.122	.961	.968	.862	.929	.931	.899
5-9	1.048	1.046	1.069	1.091	1.070	.963	1.085	1.093	1.078
10-14	.993	1.012	.876	1.005	1.004	1.001	1.035	1.015	1.065
15-19	1.001	1.037	.820	.839	.968	.986	.936	.936	1.045
20-24	1.011	1.097	.800	.930	1.045	1.083	.937	1.080	.943
25-29	1.051	1.187	.887	1.033	1.082	1.174	.992	1.114	.953
30-34	.980	1.189	.963	1.086	1.026	1.159	1.025	1.074	.967
35-39	.891	1.109	.960	1.111	.943	1.144	1.056	.998	1.005
40-44	.957	1.141	1.099	1.176	.945	1.176	1.100	.934	1.029
45-49	.809	.904	.982	.921	.786	.937	.951	.764	.981
50-54	1.086	1.074	1.356	1.094	1.024	1.144	1.130	.965	1.167
55-59	.802	.698	1.129	.780	.793	.785	.839	.785	.903
60-64	1.390	1.011	2.076	1.195	1.286	1.120	1.170	1.189	1.145
65-69	.859	.510	1.494	.776	.865	.629	.810	.871	.844
70-74	1.250	.591	2.658	1.120	1.197	.711	1.029	1.146	.945

TABLE 5.8: Estimated Factors of Age and Coverage Errors in Female Populations of Turkey, 1935-70

Age	1935	1940		1945			1950		
Group	$1+\alpha_i$	$1+\alpha_i$	$1+\beta_i$	$1+\alpha_i$	$1+\beta_i$	$1+\gamma_i$	$1+\alpha_i$	$1+\beta_i$	$1+\gamma_i$
0-4	1.025	.872	.937	.844	.854	.857	.951	.973	.837
5-9	1.156	1.078	1.134	.905	1.036	1.113	1.135	.984	.996
10-14	1.054	.991	1.031	.746	.958	1.008	1.022	.809	.926
15-19	.985	.916	.996	.771	.967	1.006	1.090	.795	1.021
20-24	1.106	.872	1.070	.862	.953	1.036	1.112	.830	1.042
25-29	1.154	1.133	1.250	1.065	1.104	1.354	1.200	.972	1.075
30-34	1.053	1.304	1.178	1.159	1.195	1.318	1.220	1.056	1.095
35-39	.910	1.184	.961	1.117	1.125	1.016	1.075	1.036	1.068
40-44	.952	1.279	.980	1.315	1.244	1.010	1.106	1.202	1.210
45-49	.702	.922	.726	1.234	.980	.751	.872	1.101	1.042
50-54	.968	1.208	.977	1.962	1.251	.986	1.009	1.631	1.296
55-59	.604	.628	.591	1.442	.715	.578	.622	1.276	.814
60-64	1.172	1.094	1.153	3.446	1.204	1.133	.914	2.675	1.326
65-69	.540	.467	.560	2.320	.551	.581	.414	1.862	.651
70-74	.925	.849	.970	4.766	.847	1.016	.491	3.559	.846

Age	1955			1960			1965		1970
Group	$1+\alpha_i$	$1+\beta_i$	$1+\gamma_i$	$1+\alpha_i$	$1+\beta_i$	$1+\gamma_i$	$1+\beta_i$	$1+\gamma_i$	$1+\gamma_i$
0-4	1.007	.905	1.122	.961	.968	.862	.929	.931	.899
5-9	1.048	1.046	1.069	1.091	1.070	.963	1.085	1.093	1.078
10-14	.993	1.012	.876	1.005	1.004	1.001	1.035	1.015	1.065
15-19	1.001	1.037	.820	.839	.968	.986	.936	.936	1.045
20-24	1.011	1.097	.800	.930	1.045	1.083	.937	1.080	.943
25-29	1.051	1.187	.887	1.033	1.082	1.174	.992	1.114	.953
30-34	.980	1.189	.963	1.086	1.026	1.159	1.025	1.074	.967
35-39	.891	1.109	.960	1.111	.943	1.144	1.056	.998	1.005
40-44	.957	1.141	1.099	1.176	.945	1.176	1.100	.934	1.029
45-49	.809	.904	.982	.921	.786	.937	.951	.764	.981
50-54	1.086	1.074	1.356	1.094	1.024	1.144	1.130	.965	1.167
55-59	.802	.698	1.129	.780	.793	.785	.839	.785	.903
60-64	1.390	1.011	2.076	1.195	1.286	1.120	1.170	1.189	1.145
65-69	.859	.510	1.494	.776	.865	.629	.810	.871	.844
70-74	1.250	.591	2.658	1.120	1.197	.711	1.029	1.146	.945

TABLE 5.9: Corrected Male Populations of Turkey (Thousands,000's)

Age	1935	1940		1945			1950		
Group	A_i	A_i	B_i	A_i	B_i	C_i	A_i	B_i	C_i
0–4	1640	1411	1716	1478	1347	1730	1736	1775	1704
5–9	1226	1211	1460	1331	1186	1420	1302	1329	1211
10–14	798.8	1075	1193	1312	1164	1381	1306	1298	1157
15–19	459.8	909.9	780.5	1040	1041	1137	1332	1284	1139
20–24	583.5	619.9	443.9	780.7	866.5	731.6	1068	1006	1007
25–29	492.0	867.4	559.2	502.6	584.2	411.8	772.0	750.4	832.9
30–34	482.2	719.6	471.3	633.9	817.3	518.7	530.4	482.8	561.2
35–39	415.6	641.3	460.4	521.6	675.9	435.6	688.0	606.9	782.6
40–44	299.1	483.6	393.7	496.5	596.6	421.4	551.3	495.7	642.3
45–49	235.7	329.3	280.0	386.3	443.6	355.4	478.3	466.4	560.5
50–54	269.9	220.7	216.7	272.2	295.8	247.5	337.2	356.7	409.5
55–59	286.2	176.5	241.1	221.7	191.5	185.1	193.8	244.4	265.5
60–64	298.2	118.9	243.5	208.5	144.4	194.1	128.7	189.9	164.0
65–69	307.1	80.0	234.5	165.3	88.4	178.1	92.4	165.5	114.6
70–74	326.6	42.0	212.7	143.5	51.1	147.4	51.6	116.0	62.1
75+	91.4	125.4	125.4	81.1	81.1	79.8	83.4	83.4	36.4
TOTAL	8212	9031	9031	9574	9574	9574	10650	10650	10650

Age	1955			1960			1965		1970
Group	A_i	B_i	C_i	A_i	B_i	C_i	B_i	C_i	C_i
0–4	1975	2090	2161	2287	2238	2216	2413	2512	2558
5–9	1612	1631	1668	1963	1910	2022	2173	2126	2304
10–14	1264	1282	1309	1707	1599	1618	1939	1886	2149
15–19	1239	1288	1280	1459	1254	1272	1687	1581	1919
20–24	1309	1305	1257	1482	1224	1273	1434	1232	1660
25–29	1117	1041	981.1	1541	1290	1286	1449	1198	1406
30–34	806.4	751.7	730.8	1164	1099	1024	1506	1261	1420
35–39	553.1	514.8	468.6	715.2	791.1	737.5	1135	1071	1471
40–44	690.9	663.7	585.5	414.3	539.9	502.5	692.9	766.5	1102
45–49	548.0	526.5	473.5	458.8	668.7	642.4	397.7	518.2	666.8
50–54	452.6	449.9	438.7	332.8	523.3	502.8	433.9	632.5	377.2
55–59	303.9	309.5	327.4	252.8	423.2	420.7	307.6	483.6	402.4
60–64	164.7	171.0	215.7	156.9	275.0	280.0	225.1	377.9	275.2
65–69	99.6	106.6	157.3	79.3	141.4	146.8	131.7	230.8	190.2
70–74	63.6	68.9	123.4	43.1	78.1	83.5	60.2	107.3	100.9
75+	96.9	96.9	119.8	108.1	108.1	137.6	129.4	130.1	43.5
TOTAL	12297	12297	12297	14164	14164	14164	16114	16114	18045

TABLE 5.10: Corrected Female Populations of Turkey (Thousands, 000's)

Age Group	1935 A_i	1940 A_i	1940 B_i	1945 A_i	1945 B_i	1945 C_i	1950 A_i	1950 B_i	1950 C_i
0-4	1315	1464	1363	1425	1407	1403	1605	1569	1824
5-9	1014	1192	1133	1394	1217	1133	1103	1273	1257
10-14	735.4	1016	975.9	1461	1138	1081	1071	1354	1182
15-19	512.7	774.1	712.4	1226	977.5	939.6	1039	1425	1110
20-24	601.6	603.3	491.7	814.3	736.3	677.6	886.5	1187	945.9
25-29	649.5	632.0	573.1	589.9	569.2	463.9	634.7	783.6	708.5
30-34	633.9	557.0	616.8	612.6	594.2	538.7	490.4	566.2	546.4
35-39	581.9	487.3	600.3	525.5	522.0	578.0	565.2	586.6	569.0
40-44	517.6	421.1	549.4	430.7	455.2	560.8	545.2	501.7	498.3
45-49	465.9	383.6	486.8	311.3	391.9	511.3	517.2	409.6	432.9
50-54	412.6	349.8	432.6	224.5	352.0	446.8	473.2	292.8	368.6
55-59	335.8	351.2	373.1	154.4	311.5	385.3	423.9	206.5	323.8
60-64	263.6	303.8	288.2	102.9	294.3	312.8	397.9	135.9	274.2
65-69	202.0	248.0	206.7	54.5	229.5	217.7	377.3	83.9	240.0
70-74	141.6	156.8	137.3	28.3	159.4	132.8	284.8	39.3	165.3
75+	122.9	114.2	114.2	115.1	115.1	87.7	126.7	126.7	94.3
TOTAL	8506	9054	9054	9470	9470	9470	10541	10541	10541

Age Group	1955 A_i	1955 B_i	1955 C_i	1960 A_i	1960 B_i	1960 C_i	1965 B_i	1965 C_i	1970 C_i
0-4	1876	2086	1683	2164	2148	2412	2456	2452	2799
5-9	1498	1502	1468	1768	1801	2002	2065	2050	2346
10-14	1105	1084	1252	1482	1483	1487	1748	1781	2042
15-19	1093	1055	1334	1262	1094	1074	1466	1467	1729
20-24	1105	1018	1396	1212	1080	1042	1244	1079	1446
25-29	977.5	865.3	1158	1140	1088	1002	1192	1061	1223
30-34	750.0	618.3	763.3	907.4	960.9	850.6	1118	1067	1169
35-39	593.1	476.7	550.4	624.7	735.9	606.6	888.5	940.8	1095
40-44	652.9	547.7	568.4	466.2	580.2	466.3	609.8	718.3	867.6
45-49	587.8	526.1	484.1	542.9	636.0	533.5	453.2	563.9	592.9
50-54	488.9	494.3	391.5	531.0	567.8	508.2	523.2	612.8	436.8
55-59	387.0	444.4	274.9	473.4	465.5	470.6	504.0	538.9	496.8
60-64	280.1	384.9	187.5	386.0	358.8	412.0	436.8	429.5	465.4
65-69	202.3	340.3	116.2	275.4	247.2	339.7	338.3	314.5	383.2
70-74	137.7	291.3	64.8	174.8	163.5	275.1	220.3	197.7	271.0
75+	158.6	158.6	200.0	181.5	181.5	108.1	230.3	219.5	218.9
TOTAL	11893	11893	11893	13591	13591	13591	15493	15493	17582

geometrically related may be aggravated by bigger age misstatements in older ages.

By using the estimates in Tables 5.7 and 5.8, corrected distributions of Turkey at the five year censuses from 1935 to 1970 were calculated and are shown in Tables 5.9 and 5.10, for males and females, respectively. It is clear from these Tables that the deficits in the adjusted distributions in all censuses do reflect the three major wars in which Turkey has been involved since 1910, namely the First World War of 1915-20, the Turkish war of Independence 1922-25 and the Second World War of 1939-45. There is evidence that Turkey experienced marked decreases in fertility rates during these periods of wars. It is worth mentioning that smaller birth cohorts are indicated for 1915-20 than 1940-45 because Turkey was not actively involved in the Second World War, though the lives of her people were strongly affected by it.

(b) Using ten year interval data:

The method described above (Section 5.3.1) has so far been applied to age data from censuses that are five years apart. However, there are very few countries that have quinquennial censuses. It is useful, therefore, to show how the method can be applied to age data from censuses of ten year intervals which are becoming more frequent in developing countries. Two approaches will be used to adapt the method to ten-year interval census data. The first approach is to follow the procedural steps as given in Table 5.6, but using ten-year instead of five-year age groups. The results of this approach are shown in Tables 5.11 and 5.13 for Fiji Islands and Mexico respectively, under '10 year' columns.

A second approach is to treat two series consisting of age groups 0-4, 10-14, 20-24 etc., and 5-9, 15-19, 25-29 etc., separately to generate factors of age and coverage errors on the same lines as in the first approach. An extra assumption is made that total reported population is correctly enumerated for the two separate subsets. Estimates from this procedure are also in Tables 5.11 and 5.13 under columns of '5-year' age groups. A discussion of these estimates follows below for the Fiji Islands and Mexico.

Fiji Islands: The method was applied to the censuses of 1946, 1956 and 1966. Table 5.11 shows that the three census method derives highly consistent results for the Fiji Islands from the five and ten year age groups in that the estimates of age and coverage error factors obtained from ten year age groups are very close to the averages of the estimates for five year groups. In addition, it is significant to note the small sizes of age and coverage errors indicated. These small estimates of errors have a good agreement with the low digit preference indices calculated for the 1966 census - 6.0 for males and 9.8 for females[1]. The slight deviation of the error factors from unity is a reflection of a good vital registration system that has evolved in the Islands for decades. Besides, Table 5.11 displays much smaller estimates of age and coverage errors in 1956 and 1966 than in 1946, which imply an appreciable improvement in the quality of age data in the more recent censuses of the Fiji Islands.

Furthermore, it is useful to examine the patterns of age and coverage errors in Fiji censuses as displayed in Table 5.12. The Table exhibits under-reporting in the youngest five year age group followed by the over-reporting from 5-15 years for both sexes. Then, for males under-reporting is indicated for the 15-19 age group, whilst the females

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1. See: "Report on the Census of the Population, 1966", The Colony of Fiji, Government Printer, Suva, Fiji, 1967.

TABLE 5.11: Comparison of estimated factors of age errors from 5-year and 10-year age groups of Fiji Populations

Age Group	MALES 1946		1956		1966	
	5-yr	10-yr	5-yr	10-yr	5-yr	10-yr
0-4	.939	} .985	.976	} .989	1.015	} .993
5-9	1.044		1.015		.988	
10-14	.987	} .991	1.017	}1.006	1.049	}1.022
15-19	.992		.997		1.002	
20-24	.971	}1.016	.971	} .993	.971	} .971
25-29	1.058		1.015		.974	
30-34	.996	}1.056	.974	}1.018	.951	} .982
35-39	1.108		1.061		1.015	
40-44	1.112	}1.121	1.050	}1.081	.990	}1.042
45-49	1.094		1.093		1.092	
50-54	1.115	}1.042	1.090	}1.047	1.065	}1.051
55-59	.937		.966		.996	
60-64	1.416	}1.027	1.252	}1.029	1.107	}1.032
65-69	.706		.799		.905	
70-74	.777	} .578	.841	} .685	.911	} .812
75-79	.437		.555		.705	

Age Group	FEMALES 1946		1956		1966	
	5-yr	10-yr	5-yr	10-yr	5-yr	10-yr
0-4	.955	} .992	.957	} .987	.959	} .983
5-9	1.033		1.020		1.007	
10-14	1.046	}1.013	1.031	}1.019	1.016	}1.026
15-19	.977		1.005		1.034	
20-24	1.098	}1.070	1.068	}1.044	1.038	}1.018
25-29	1.042		1.018		.994	
30-34	1.068	}1.011	1.040	}1.012	1.014	}1.013
35-39	.954		.983		1.013	
40-44	1.069	} .986	1.048	} .994	1.028	}1.001
45-49	.919		.946		.974	
50-54	.999	} .940	1.026	} .962	1.055	} .985
55-59	.914		.913		.913	
60-64	.811	} .851	.915	} .893	1.033	} .938
65-69	.966		.900		.837	
70-74	.541	} .788	.628	} .780	.730	} .773
75-79	1.586		1.169		.862	

TABLE 5.12: The Estimated Factors of Age and Coverage Errors for Male and Female Populations of the Fiji Islands

Age	1946		1956		1966	
Group	Males	Females	Males	Females	Males	Females
0-4	.939	.955	.976	.957	1.015	.959
5-9	1.044	1.033	1.015	1.020	.988	1.007
10-14	.987	1.046	1.017	1.031	1.049	1.016
15-19	.992	.977	.997	1.005	1.002	1.034
20-24	.971	1.098	.971	1.068	.971	1.038
25-29	1.058	1.042	1.015	1.018	.974	.994
30-34	.996	1.068	.974	1.040	.951	1.014
35-39	1.108	.954	1.061	.983	1.015	1.013
40-44	1.112	1.069	1.050	1.048	.990	1.028
45-49	1.094	.919	1.093	.946	1.092	.974
50-54	1.115	.999	1.090	1.026	1.065	1.055
55-59	.937	.914	.966	.913	.996	.913
60-64	1.416	.811	1.252	.915	1.107	1.033
65-69	.706	.966	.799	.900	.905	.837
70-74	.777	.541	.841	.628	.911	.730
75-79	.437	1.586	.555	1.169	.705	.862

are over-reported over the 20-35 age range. Some compensating errors are seen in the female age structure between 35 and 70 years in the 1966 census. Contrary to the expected pattern, males are shown to be under-reported in the advanced ages. In both sexes, there is a general picture of progressively systematic age errors implying deterioration of the quality of age data with higher ages. However, care is necessary in the interpretation of Table 5.12 because of the heterogenous nature of the population of the Fiji Islands.

Mexico: Application of the method was made to the censuses of 1950, 1960 and 1970. As in the case of the Fiji Islands, the results for Mexico display a high degree of consistency. The estimates of ten year age grouping are very close to the corresponding averages of the five-year age grouping - see Table 5.13. In addition, the deviations of the factors of errors from unity are estimated to be small, mainly because Mexico has had a long history of fairly reliable systems of vital registration. However, the estimated age and coverage errors are higher in Mexico than in the Fiji Islands, possibly because the census takers had a more formidable task to deal with the much bigger population of Mexico than with the smaller population of the Fiji Islands. Furthermore, Table 5.13 shows smaller estimates of errors in most of the age groups, especially in the older ages, in the more recent censuses. This implies that there has been a marked improvement in the quality of age data over the last three censuses.

Table 5.14 shows a remarkably similar pattern of age and coverage errors in Mexico at the 1950, 1960 and 1970 censuses. Firstly, the age group 0-4 is shown to have been under-enumerated, probably due to omissions and small errors in more recent censuses. Secondly, more

TABLE 5.13: Comparison of the estimated factors of age errors from 5-year and 10-year age groups of Mexican Populations

	Age Group	1950 5-yr	1950 10-yr	1960 5-yr	1960 10-yr	1970 5-yr	1970 10-yr
MALES	0-4	.921	.976	.947	.986	.973	.996
	5-9	1.035		1.026		1.017	
	10-14	1.061	1.042	1.087	1.046	1.114	1.050
	15-19	1.014		.993		.972	
	20-24	.953	1.017	.961	.986	.969	.956
	25-29	1.093		1.012		.937	
	30-34	.969	1.048	.944	1.025	.921	1.003
	35-39	1.147		1.123		1.099	
	40-44	1.030	.990	.990	.992	.952	.994
	45-49	.969		1.005		1.043	
	50-54	1.085	.898	1.016	.920	.951	.942
	55-59	.743		.836		.941	
	60-64	1.378	.967	1.203	.980	1.050	.993
	65-69	.625		.770		.949	
	70-74	1.404	.917	1.310	.994	1.223	1.079
	75-79	1.541		.708		.926	
FEMALES	0-4	.928	.974	.943	.983	.957	.992
	5-9	1.032		1.005		.978	
	10-14	1.030	1.052	1.057	1.053	1.085	1.055
	15-19	1.100		1.054		1.009	
	20-24	1.096	1.106	1.085	1.074	1.074	1.043
	25-29	1.149		1.084		1.023	
	30-34	.983	1.041	.971	1.025	.959	1.008
	35-39	1.136		1.120		1.103	
	40-44	1.002	.947	.977	.950	.953	.954
	45-49	.908		.953		.999	
	50-54	.967	.823	.948	.849	.929	.876
	55-59	.657		.758		.873	
	60-64	1.089	.860	1.030	.880	.974	.900
	65-69	.540		.691		.884	
	70-74	1.007	.852	1.014	.884	1.021	.917
	75-79	.467		.630		.851	

TABLE 5.14: The Estimated Factors of Age and Coverage Errors of Male and Female Populations of Mexico

Age Group	1950 Males	1950 Females	1960 Males	1960 Females	1970 Males	1970 Females
0-4	.921	.928	.947	.943	.973	.957
5-9	1.035	1.032	1.026	1.005	1.017	.978
10-14	1.061	1.030	1.087	1.057	1.114	1.085
15-19	1.014	1.100	.993	1.054	.972	1.009
20-24	.953	1.096	.961	1.085	.969	1.074
25-29	1.093	1.149	1.012	1.084	.937	1.023
30-34	.969	.983	.944	.971	.921	.959
35-39	1.147	1.136	1.123	1.120	1.099	1.103
40-44	1.030	1.002	.990	.977	.952	.953
45-49	.969	.908	1.005	.953	1.043	.999
50-54	1.085	.967	1.016	.948	.951	.929
55-59	.743	.657	.836	.758	.941	.873
60-64	1.378	1.089	1.203	1.030	1.050	.974
65-69	.625	.540	.770	.691	.949	.884
70-74	1.404	1.007	1.310	1.014	1.223	1.021
75-79	.541	.467	.708	.630	.926	.851

compensating errors are noticeable in the middle range of ages of both sexes which indicate substantial transfers of populations over age group borders and erratic errors. Next, women are shown under-reported in older ages while men are over-reported in some of the old ages. This is a common feature of age data where females want to appear younger while males like to appear older for social reasons. In addition, age and coverage errors are indicated to be progressively higher with older ages, implying that older people have poor memories. Lastly, in older ages in males, age groups including digit 0 have a tendency to over-statement, while under-statement is found in age groups including digit 5 - a phenomenon that underscores the belief that older people favour reporting ages ending in 0 more than any other digit.

5.4. Comparing results from the three censuses and Demeny-Shorter methods

It is useful to compare the results of our method with estimates derived by the Demeny-Shorter technique. To do this we shall use some of the results of our earlier example in Table 5.6 and compare them with those in Table 5.3. The necessary estimates from Tables 5.3 and 5.6,[1/] namely the correction factors for 1955 and 1960 censuses obtained by the Demeny-Shorter and our method, are given in Table 5.15.

It is notable that the correction factors from the two methods are reasonably close in many age groups. This implies that if one of the methods gives good estimates, the results from the other are also plausible. In addition, the correction factors of the Demeny-Shorter technique in most age groups are in the same direction as one of the two corresponding correction factors from the three census method. Thus, the patterns of

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1. Note that the correction factors from the three census method shown in Table 5.15 are the reciprocals of the $1+\alpha_i$ and $1+\beta_i$ in Table 5.6.

TABLE 5.15: Comparison of Correction Factors obtained by Demeny-Shorter and three-census methods from Turkish Female data of 1955 and 1960 censuses

Age Group	CORRECTION FACTORS		
	DEMENY-SHORTER METHOD	THREE CENSUS METHOD	
		1955	1960
0-4	1.039	.997	1.033
5-9	.976	.954	.935
10-14	1.020	1.007	.996
15-19	1.047	1.000	1.033
20-24	1.002	.989	.957
25-29	.937	.951	.924
30-34	.960	1.020	.975
35-39	.998	1.122	1.060
40-44	.941	1.045	1.058
45-49	1.146	1.236	1.272
50-54	.906	.921	.977
55-59	1.240	1.247	1.261
60-64	.774	.719	.778
65-69	1.244	1.164	1.156
70-74	.893	.800	.835

age error disclosed by the two approaches are similar. This is hardly surprising since the application of the three census method verifies that the age errors in 1960 were much the same as the 1955. The Demeny-Shorter assumptions are, therefore, reasonably accurate. If this was not the case, then much bigger discrepancies would have arisen.

5.5. Conclusion:

In this chapter, a critical appraisal of the assumptions of the Demeny-Shorter method in regard to its applicability to African data and to its flexibility has been made. The study made shows that the Demeny-Shorter method is not flexible enough to examine age data from African countries, which have had different demographic experience and census intervals from those of Turkey. Even with Turkish data the results obtained are sensitive to changes in coverage at successive censuses. Although taking censuses in pairs from a series may give reasonable estimates if changes in age errors occur slowly, such a procedure does not make full use of the information.

An attempt to use a more flexible and suitable method has been made by introducing a three-censuses analysis. This method depends on two of the three assumptions made by the Demeny-Shorter method, namely the selected model life table and correct enumerated total population. However, the three-census method has several disadvantages. Firstly, like the Demeny-Shorter method, it depends on a selected life table which introduces some rigidity in its operation and results, although the chosen survivorship ratios have to be reconciled with the observed ratios. Secondly, the technique involves many more computations than the two census Demeny-Shorter method. This, however, is no longer a serious problem with the advent of modern electronic computers which do the work in a matter of seconds. Thirdly, at present, applicability of the method to data from developing countries is restricted to a handful of countries and it is academic in African situations. This is because the method uses data from three censuses which must be of equal intervals, preferably of five or ten years.

Nevertheless, by replacing the Demeny-Shorter assumption of constant error by regular change of error at successive censuses, the three-census method is likely to be more realistic. This follows from the many attempts made by census organisers in developing countries to reduce errors by adopting better methods of data collection (as already reported in Chapter 1). Furthermore, it is significant that the results of the three-censuses method, when applied to a series of Turkish censuses, are highly consistent in the younger age groups; when applied to the Fiji Islands and Mexican data, the results agree closely with evidence from other studies. In view of these encouraging results, it is hoped that the method will be tested and found useful as more censuses with smaller errors are conducted in developing countries which are experiencing a rapid improvement in social survey methods.

CHAPTER SIX

ESTIMATING AGE DISTRIBUTIONS FROM TWO SUCCESSIVE CENSUSES

6.1. Introduction

A 'true' population age distribution reflects past real fluctuations, namely variations in fertility, mortality and migration. With accurate information on real fluctuations, a true population age structure can, therefore, be estimated. In most developing countries, however, this accurate information is lacking due to absence of complete vital registration data. Nevertheless, methods that derive true age distributions by using age distributions observed at two successive censuses have been evolved.

A notable method of this kind was developed by Paul Demeny and Frederic Shorter (1968) in their study of Turkish six quinquennial censuses. The Demeny-Shorter method uses life tables survivorship ratios to relate the age reports of successive censuses. The method is difficult to apply to data from developing countries because of possible large international migration and big changes in coverage. In addition, where there are great doubts about the level and pattern of mortality, the introduction of an estimated life table may cause more distortion in the ages. A simpler method based on the same idea may be justified.

In this chapter we shall present a method which uses percent age distributions from two successive censuses in order to estimate real fluctuations. The derived real fluctuations will then be used to estimate the true age distributions at the two censuses. This technique will be presented in three forms:- (i) to utilise data collected at five-year interval censuses; (ii) to use ten-year interval census data;

(iii) to derive single year real fluctuations reported at five or ten year interval censuses.

6.2. The method of percent age distributions of two censuses

Three assumptions are made in the method. They are, firstly, that the underlying smooth structure of the age distributions that would result if erratic time fluctuation and coverage of age errors were eliminated is unchanged between the two censuses; secondly, that the age and residual coverage errors are the same at each census, that is, excluding any proportional coverage change which is common to every age group; thirdly, that there is no migration in the intercensal period.

Taking percentage age distributions of two consecutive censuses we have:-

Age group i	Census A	Census B	
1	$S_1(1+\lambda_1)(1+\varepsilon_1)$	$S_1(1+\lambda)(1+\varepsilon_1)$	
2	$S_2(1+\lambda_2)(1+\varepsilon_2)$	$S_2(1+\lambda_1)(1+\varepsilon_2)$	
3	$S_3(1+\lambda_3)(1+\varepsilon_3)$	$S_3(1+\lambda_2)(1+\varepsilon_3)$	
.	.	.	
.	.	.	...(6.1)
.	.	.	
n	$S_n(1+\lambda_n)(1+\varepsilon_n)$	$S_n(1+\lambda_{n-1})(1+\varepsilon_n)$	

where $S_1, S_2, S_3, \ldots\ldots\ldots, S_n$ are smooth age structure;

$\lambda_1, \lambda_2, \lambda_3, \ldots\ldots\ldots\ldots, \lambda_n$ are real fluctuations in age distributions that are due to fertility, mortality and migration; and

$\varepsilon_1, \varepsilon_2, \varepsilon_3, \ldots\ldots\ldots\ldots, \varepsilon_n$ are age and coverage errors.

Let $A_i = S_i(1+\lambda_i)(1+\varepsilon_i)$ ie. the reported percentage of the age group i to the total population in Census A - first census; and

$B_i = S_i(1+\lambda_{i-1})(1+\varepsilon_i)$ ie. the reported percentage of the age group i to the total population in Census B - second census.

Dividing A_i by B_i gives:-

$$
\begin{aligned}
R_1 &= A_1/B_1 = (1+\lambda_1)/(1+\lambda) \\
R_2 &= A_2/B_2 = (1+\lambda_2)/(1+\lambda_1) \\
R_3 &= A_3/B_3 = (1+\lambda_3)/(1+\lambda_2) \\
&\;\;\vdots \\
R_n &= A_n/B_n = (1+\lambda_n)/(1+\lambda_{n-1})
\end{aligned}
\qquad \text{..............(6.2)}
$$

since $(1+\varepsilon_i)$'s cancel out.

Successive multiplication of the R_i's yields:-

$$
\begin{aligned}
\pi_1 &= R_1 = (1+\lambda_1)/(1+\lambda) \\
\pi_2 &= R_1.R_2 = (1+\lambda_2)/(1+\lambda) \\
\pi_3 &= R_1.R_2.R_3 = (1+\lambda_3)/(1+\lambda) \\
&\;\;\vdots \\
\pi_n &= R_1.R_2.R_3. \;..........\; R_n = (1+\lambda_n)/(1+\lambda)
\end{aligned}
\qquad \text{..............(6.3)}
$$

Hence:-

$$
\begin{aligned}
(1+\lambda_1) &= \pi_1(1+\lambda) \\
(1+\lambda_2) &= \pi_2(1+\lambda) \\
(1+\lambda_3) &= \pi_3(1+\lambda) \\
&\;\;\vdots \\
(1+\lambda_n) &= \pi_n(1+\lambda)
\end{aligned}
\qquad \text{.............(6.4)}
$$

where $(1+\lambda)$ is the real fluctuation in the youngest cohort of the latest census under consideration. Thus, the true fluctuations are expressed in terms of that for the lowest age group. These fluctuations provide the evidence required for studies of changes due to birth, mortality and migration variations. In particular at younger ages birth trends may be detected.

Now, to reconstruct the true age distribution the $S_1, S_2, S_3, \ldots, S_n$ are determined by some smoothing process. Thus:-

$$1 \times S_1 + \pi_1 . S_2 + \pi_2 . S_3 + \ldots\ldots\ldots\ldots + \pi_{n-1} . S_n = \frac{\sum B_i}{1+\lambda}^{*} \quad \ldots\ldots(6.5)$$

Since $\sum B_i$ is 100%, $1+\lambda$ can be determined. Then we use equation in (6.4):

$(1+\lambda_i) = \pi_i(1+\lambda)$. The 'true' distribution is estimated by: $S_i(1+\lambda_i)$ and $S_i(1+\lambda_{i-1})$ for censuses A and B respectively, where $i = 1, 2, \ldots\ldots, n$ age groups.

Therefore, re-stating equations in (6.1) without the error component gives us:-

Age group i	Census A	Census B
1	$S_1(1+\lambda_1)$	$S_1(1+\lambda)$
2	$S_2(1+\lambda_2)$	$S_2(1+\lambda_1)$
3	$S_3(1+\lambda_3)$	$S_3(1+\lambda_2)$
.	.	.
.	.	.
.	.	. ....(6.6)
n	$S_n(1+\lambda_n)$	$S_n(1+\lambda_{n-1})$

as a schematic representation of the estimated 'true' age distributions of censuses A and B.

* On the assumption that ϵ_i are due to age errors and therefore $\sum_i B_i = \sum_i (1+\lambda_{i-1}) S_i$

6.3. The Period-Age Interval Method Applied to Five-Year Intercensal Data

The computational procedure in the above method is illustrated in Table 6.1 where an example of Turkish female age data in 1955 and 1960 censuses is given. The procedure is easy to follow from the example and need not be described here, except to mention two steps: first, the smooth age structure in column 5 is located by e_5^o = 63.5 and r = 2.5% from the South family of model stable population distributions in the Coale-Demeny Regional Tables (1966) in accordance with Coale-Demeny procedure (1967); secondly, the last two columns (10 and 11) of Table 6.1 display percent distributions adjusted to make a total of 100. The computer program for the entire calculations is in the Appendices.

(a) Importance of estimating λ_i

As can be seen in column 7 of Table 6.1, the estimation of λ_i is important, even if the S_i (underlying smooth age structure) cannot be easily estimated, in that λ_i gives the estimated changes in the underlying smooth structure that are due to the past variations in the levels and patterns of fertility, mortality and migration. Since, in the absence of catastrophic events, such as wars, famines and epidemics, effects of changing mortality compared with fertility on the age structure of human populations are small[1/], the value of λ_i represents the changes in birth rates , or at least the balance of the mortality and fertility effects where fertility effects are predominant. Migration fluctuations simulate birth variations which may have an appreciable influence at ages beyond childhood. Because the underlying smooth age structure has fixed

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1. For proof see Coale, A.J., "How the Age Distribution of a Human Population is Determined", Cold Spring Harbor Symposia on Quantitative Biology, Vol.XXII(1957) pp.83-99; or Bourgeois-Pichat (1968), "The Concept of Stable Population, Application to the Study of Populations of Countries with Incomplete Demographic Statistics, Population Studies No.39, United Nations, New York.

TABLE 6.1: Computational Procedure of the Period-Age Interval Method - Applied to Turkish female data of 1955 and 1960 censuses

AGE GROUP	i	REPORTED DISTRIBUTION of 1955 (A_i)	1960 (B_i)	RATIO 1955-1960 $A_i/B_i=R_i$	CHAINED RATIOS π_i	SMOOTH STRUCTURE S_i	$1 \times S_i$ and $\pi_{i-1} \cdot S_i$	REAL FLUCTUATION $1+\lambda_i=\pi_i(1+\lambda)$ where $1+\lambda= .9945$	FIRST ESTIMATES OF TRUE DISTRIBUTIONS $S_i(1+\lambda_i)$ 1955	$S_i(1+\lambda_{i-1})$ 1960	FINAL ESTIMATES OF TRUE DISTRIBUTIONS 1955	1960
		1	2	3	4	5	6	7	8	9	10	11
0-4	1	15.88	15.30	1.0379	1.0379	15.25	15.25	1.0322	15.74	15.17	15.92	15.33
5-9	2	13.20	14.19	.9302	.9655	12.89	13.38	.9602	12.38	13.30	12.52	13.44
10-14	3	9.22	10.96	.8412	.8122	11.28	10.89	.8077	9.11	10.83	9.21	10.95
15-19	4	9.20	7.70	1.1810	.9592	9.85	8.00	.9539	9.40	7.96	9.51	8.05
20-24	5	9.39	8.30	1.1313	1.0852	8.59	8.24	1.0792	9.27	8.19	9.37	8.28
25-29	6	8.64	8.66	.9977	1.0827	7.46	8.10	1.0767	8.03	8.05	8.12	8.14
30-34	7	6.18	7.25	.8524	.9229	6.48	7.02	.9178	5.95	6.98	6.02	7.06
35-39	8	4.44	5.10	.8706	.8035	5.59	5.16	.7990	4.47	5.13	4.52	5.19
40-44	9	5.25	4.04	1.2995	1.0441	4.85	3.90	1.0383	5.04	3.88	5.10	3.92
45-49	10	4.00	3.68	1.0870	1.1349	4.16	4.34	1.1286	4.70	4.32	4.75	4.37
50-54	11	4.46	4.28	1.0421	1.1826	3.54	4.02	1.1761	4.16	4.00	4.21	4.04
55-59	12	2.61	2.72	.9596	1.1348	2.98	3.52	1.1285	3.36	3.50	3.40	3.54
60-64	13	3.27	3.39	.9646	1.0946	2.44	2.77	1.0886	2.66	2.75	2.69	2.78
65-69	14	1.46	1.57	.9299	1.0179	1.94	2.12	1.0123	1.96	2.11	1.98	2.13
70-74	15	1.45	1.44	1.0069	1.0250	1.39	1.41	1.0194	1.42	1.41	1.44	1.43
75-79	16	.52	.59	.8814	.9034	.85	.87	.8984	.76	.87	.77	.88
80+	17	.83	.83	--	--	--	--	--	.46	.46	.47	.47
		100.00	100.00	--	--	99.54	98.99	--	98.87	98.91	100.00	100.00

fertility and mortality schedules, the pattern formed by the $(1+\lambda_i)$'s indicates the trend of real fluctuations (mainly in birth rates) prior to the censuses used. Thus, by comparing adjacent values of $1+\lambda_i$, it is possible to indicate the direction of the changes. A bigger value means a higher birth rate while a smaller value implies a lower rate (including "late" births from migration). For example, in column 7 of Table 6.1 the values of $1+\lambda$ calculated for periods 1955-60, 1950-55, 1945-50 and 1940-45 are .9945 , 1.0332, .9602 and .8077 respectively. These estimates suggest that the order of highest to lowest rates is 1950-55, 1955-60, 1945-50 and 1940-45. However, it should be pointed out that this interpretation of $(1+\lambda_i)$, in terms of changes in birth rates only, becomes less meaningful with advanced ages because of accumulated mortality effects and the impact of migration. Further discussion of the importance of λ_i, especially in terms of specific countries' demographic experiences,is provided for Turkey and Malawi below.

(b) Turkey

Turkey's long series of successive censuses taken at five year intervals between 1935 and 1970 provides very suitable data for our study. Tables 6.2 and 6.3 show estimates of real fluctuations in Turkish male and female age distributions, respectively, at quinquennial censuses of 1935-1970. An examination of these tables show that the method yields quite consistent estimates of real fluctuations for the same rates. The estimates from male data are very close in values and similar in pattern to the results from the female data. This rather close agreement suggests a fair degree of reliability in the results from the method. The odd values shown in the Tables obtained from the 1940-45 period are no surprise , as the Second World War disruptions of normal life, to which Turkey was no exception, resulted in poor quality data collected at the time.

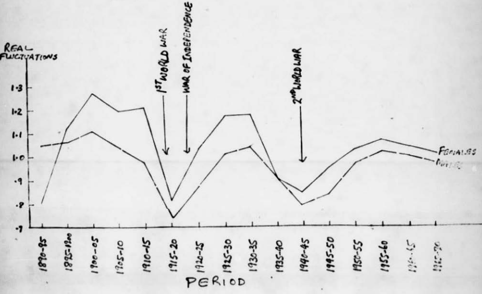
TABLE 6.2: Estimates of Real Fluctuations of Successive Time Periods From the Period-Age Interval Method - Turkish Males

Age Group in 1965-1970	1965-1970	1960-1965	1955-1960	1950-1955	1945-1950	1940-1945	1935-1940	Period of Fluctuations	
0-4	1.012							1965-70	
5-9	1.042	1.022						1960-65	
10-14	1.067	1.074	1.023					1955-60	
15-19	1.027	1.037	1.070	1.009				1950-55	
20-24	.948	.962	1.004	.937	.985			1945-50	
25-29	.846	.881	.891	.869	.892	1.026		1940-45	World War 2
30-34	.905	.980	1.024	.994	1.002	1.174	1.000	1935-40	
35-39	1.178	1.195	1.202	1.176	1.126	1.310	1.162	1930-35	
40-44	1.174	1.219	1.169	1.119	1.036	1.287	1.116	1925-30	
45-49	1.033	1.033	.984	.987	.921	1.080	.896	1920-25	War of Indep.
50-54	.817	.830	.789	.803	.683	.761	.680	1915-20	World War 1
55-59	1.212	1.240	1.215	1.235	1.064	1.141	1.094	1910-15	
60-64	1.200	1.237	1.250	1.188	1.047	1.023	1.120	1905-10	
65-69	1.267	1.311	1.351	1.315	1.149	1.055	1.193	1900-05	
70-74	1.121	1.209	1.211	1.178	1.028	.961	1.106	1895-1900	
75-79	.809	.894	.923	.900	.834	.771	.866	1890-95	
		.776	.799	.846	.740	.717	.779	1885-90	
			.809	.895	.839	.781	.799	1880-85	
				.817	.800	.788	.831	1875-80	
					.932	.848	.862	1870-75	
						.928	.978	1865-70	
							1.209	1860-65	

TABLE 6.3: Estimates of Real Fluctuations of Successive Time Periods From the Period-Age Interval Method - Turkish Females

Age Group in 1965-1970	1965-1970	1960-1965	1955-1960	1950-1955	1945-1950	1940-1945	1935-1940	Period of Fluctuations
0-4	.976							1965-70
5-9	1.003	.989						1960-65
10-14	1.020	1.023	.994					1955-60
15-19	.970	.993	1.032	.996				1950-55
20-24	.837	.933	.960	.908	.970			1945-50
25-29	.796	.817	.808	.817	.850	.972		1940-45 World War 2
30-34	.906	.922	.954	.920	.952	1.080	.968	1935-40
35-39	1.040	1.056	1.079	1.075	1.057	1.151	1.088	1930-35
40-44	1.010	1.053	1.077	1.071	.981	1.110	1.057	1925-30
45-49	.877	.876	.918	.895	.778	.871	.867	1920-25 War of Indep.
50-54	.739	.807	.799	.821	.714	.683	.657	1915-20 World War 1
55-59	.978	1.044	1.038	1.065	.945	.815	.885	1910-15
60-64	1.036	1.141	1.129	1.160	1.017	.871	.985	1905-10
65-69	1.114	1.150	1.176	1.242	1.063	.895	.963	1900-05
70-74	1.066	1.203	1.129	1.261	1.008	.891	.942	1895-1900
75-79	1.051	1.046	1.089	1.208	1.035	.856	.917	1890-95
		1.038	1.012	1.274	.973	.859	.905	1885-90
			1.019	1.292	1.055	.892	.911	1880-85
				1.185	.955	.875	.892	1875-80
					1.027	.836	.882	1870-75
						.860	.882	1865-70
							.925	1860-65

Figure 6.1: Estimated Pattern of real fluctuations between 1890 and 1970 in Turkey *



* The values on the vertical axis corresponding to the points on the graph are the estimates obtained by the use of the 1965 and 1970 census data.

Furthermore, it is satisfying to note that the estimates of real fluctuations agree well with what is believed to have happened to fertility in Turkey since early this century. Both Tables 6.2 and 6.3 and Figure 6.1 suggest that substantial declines took place in fertility during the war periods, which were from 1915 to 1920, when Turkey was a major aliy of Germany in the First World War; 1920 to 1925 when Turkey was fighting the War of Independence, and from 1940 to 1945 - the Second World War period. In addition to the Second World War influence, the depressed estimates of 1935-50 are largely a result of the low proportions in the early reproductive age group, which are traceable to the low birth rates of 1915-25 war period. This depressing influence of the 1915-25 wars on birth rates is repeated at later periods, namely 1960-70, though to a lesser extent. Besides, the estimates in Tables 6.2 and 6.3 and Figure 6.1 show higher birth rates in the pre-war and inter-war periods (before 1915 and between 1925 and 1939 respectively), than in the war period. Also suggested by the Tables and graph is a near constant fertility level in post-war Turkey (between 1945 and 1960) and a slight decline in the level during the 1960s.

When smooth age structures are subjected to the estimated real fluctuations, 'true' age distributions are derived. These estimated age-sex distributions for pairs of successive censuses in Turkey, 1935 to 1970, are given in Tables 6.4 and 6.5. For all except the end years there are thus two adjusted age distributions. These Tables show estimates which are close for the same age groups in the same year for the two attempts, thus reflecting the close agreement of the real fluctuations estimated for particular periods in Tables 6.2 and 6.3.

In addition, a comparison of the present method and the Demeny-Shorter method is made by using the final age distributions obtained from the application of both methods to the Turkish female data of 1955 and 1960

TABLE 6.4: Corrected % Age Distributions of Turkish Males 1935-1970

Age Group	i	1935 A_i	1940 B_i	1940 A_i	1945 B_i	1945 A_i	1950 B_i	1950 A_i	1955 B_i	1955 A_i	1960 B_i	1960 A_i	1965 B_i	1965 A_i	1970 B_i
0-4	1	16.69	14.41	15.98	13.96	14.62	16.05	14.94	16.07	15.54	14.90	16.27	15.51	15.92	15.47
5-9	2	13.21	13.81	14.25	12.75	13.36	11.81	11.29	12.17	12.44	13.27	13.16	13.66	13.73	13.43
10-14	3	9.59	11.97	12.81	13.01	13.25	11.71	11.40	9.96	9.67	10.92	10.64	11.50	11.53	11.99
15-19	4	6.60	8.72	9.89	11.77	10.79	11.64	11.75	9.92	9.73	8.47	8.49	9.28	9.30	10.08
20-24	5	9.50	5.93	6.30	8.94	8.39	9.39	9.67	10.16	9.95	8.50	8.19	7.37	7.21	8.08
25-29	6	8.65	8.48	8.48	5.65	5.43	7.25	7.33	8.31	8.42	8.66	8.64	7.10	6.68	6.25
30-34	7	8.17	7.70	6.82	7.59	7.33	4.68	5.13	6.29	6.16	7.33	7.60	7.46	7.50	5.77
35-39	8	6.73	7.27	6.28	6.08	6.25	6.32	6.76	4.39	4.26	5.33	5.54	6.55	6.45	6.48
40-44	9	4.62	5.93	5.06	5.54	5.90	5.34	5.53	5.74	5.66	3.69	3.79	4.74	4.86	5.53
45-49	10	3.61	4.02	3.55	4.41	4.49	4.99	5.16	4.66	4.98	4.85	4.81	3.23	3.27	4.14
50-54	11	3.16	3.09	2.81	3.02	3.04	3.73	3.84	4.28	4.54	4.20	4.00	4.02	4.06	2.73
55-59	12	2.73	2.63	2.53	2.33	2.20	2.45	2.37	3.11	3.35	3.74	3.47	3.29	3.29	3.33
60-64	13	2.24	2.16	1.99	1.96	1.92	1.68	1.74	1.85	2.04	2.68	2.50	2.73	2.74	2.60
65-69	14	1.84	1.63	1.52	1.40	1.25	1.31	1.35	1.27	1.34	1.55	1.38	1.87	1.81	2.04
70-74	15	1.48	1.19	1.01	.92	.97	.83	.81	.88	.94	.93	.80	.93	.89	1.22
75-79	16	.87	.76	.52	.47	.48	.49	.43	.44	.55	.55	.41	.45	.41	.51
80+	17	.30	.30	.20	.20	.33	.33	.50	.50	.43	.43	.31	.31	.35	.35
TOTAL		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 6.5: Corrected % Age Distributions of Turkish Females - 1935-1970

Age Group	i	1935 A_i	1940 B_i	1940 A_i	1945 B_i	1945 A_i	1950 B_i	1950 A_i	1955 B_i	1955 A_i	1960 B_i	1960 A_i	1965 B_i	1965 A_i	1970 B_i
0-4	1	17.66	15.65	16.60	14.87	14.36	16.28	14.70	16.18	15.92	15.33	16.13	15.60	16.26	15.79
5-9	2	13.69	14.04	13.96	13.03	12.98	11.52	10.91	12.15	12.52	13.44	13.18	13.57	13.93	13.67
10-14	3	10.03	12.17	12.23	12.61	12.67	11.35	10.65	9.49	9.21	10.95	10.80	11.49	11.55	12.12
15-19	4	6.83	8.97	8.79	11.14	10.38	11.10	10.82	9.29	9.51	8.05	8.26	9.43	8.70	10.07
20-24	5	8.18	6.05	6.23	7.91	7.20	9.03	9.31	9.38	9.37	8.28	8.10	7.19	7.21	7.56
25-29	6	8.06	7.20	6.67	5.57	5.77	6.24	6.70	8.05	8.12	8.14	8.05	7.02	7.11	6.23
30-34	7	6.93	7.06	6.37	5.94	6.62	4.97	5.28	5.78	6.02	7.06	6.95	6.97	7.07	6.14
35-39	8	5.96	6.06	5.84	5.65	6.17	5.70	5.90	4.56	4.52	5.19	5.00	6.01	5.94	6.10
40-44	9	5.08	5.20	4.99	5.00	5.57	5.29	5.47	5.05	5.10	3.92	3.97	4.30	4.44	5.11
45-49	10	4.37	4.41	4.38	4.54	4.55	4.77	4.99	4.68	4.75	4.37	4.40	3.40	3.22	3.81
50-54	11	3.78	3.75	3.85	3.81	3.98	3.85	4.28	4.23	4.21	4.04	4.10	3.74	3.62	2.73
55-59	12	3.12	3.17	3.38	3.25	3.11	3.28	3.40	3.56	3.40	3.54	3.45	3.43	3.21	3.02
60-64	13	2.45	2.48	2.66	2.69	2.68	2.47	2.88	2.74	2.69	2.78	2.93	2.81	2.81	2.61
65-69	14	1.79	1.78	1.82	1.90	1.79	1.97	2.17	2.15	1.98	2.13	1.97	2.28	2.08	2.17
70-74	15	1.18	1.12	1.14	1.11	1.25	1.16	1.38	1.51	1.44	1.43	1.38	1.39	1.45	1.47
75-79	16	0.59	0.59	.65	.55	.57	.67	.75	.79	.77	.88	.80	.84	.87	.87
80+	17	0.30	0.30	.44	.43	.35	.35	.41	.4[illegible]	.47	.47	.53	.53	.53	.53
TOTAL		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 6.6: A comparison of the corrected Age Structures obtained by the application of the Period-Age Interval Method and Demeny-Shorter (D-S) method to Turkish female population data of 1955 and 1960 censuses

Age	1955		1960	
Group	Our Method	D-S Method	Our Method	D-S Method
0-4	15.92	16.50	15.33	15.90
5-9	12.52	12.89	13.44	13.86
10-14	9.21	9.40	10.95	11.18
15-19	9.51	9.63	8.05	8.16
20-24	9.37	9.41	8.28	8.32
25-29	8.12	8.09	8.14	8.11
30-34	6.02	5.93	7.06	6.96
35-39	4.52	4.43	5.19	5.10
40-44	5.10	4.94	3.92	3.80
45-49	4.75	4.58	4.37	4.22
50-54	4.21	4.04	4.04	3.88
55-59	3.40	3.24	3.54	3.37
60-64	2.69	2.53	2.78	2.63
65-69	1.98	1.82	2.13	1.96
70-74	1.44	1.29	1.43	1.29
75+	1.24	1.28	1.35	1.28
TOTAL	100.00	100.00	100.00	100.02

censuses. Table 6.6 is formed by use of the percentages of the Demeny-Shorter results and the final two columns of Table 6.1. It is clear from Table 6.6 that the patterns and levels of results from the two methods are in close agreement. For instance, both the estimated true age distributions show deficiencies in the age groups affected by lower birth rates traceable to war. The patterns and levels of the results from the two methods agree.

(c) Malawi

The only African country that has carried out two large-scale demographic inquiries at an interval of five years is Malawi. The inquiries are the 1966 census and the 1971-72 national sample survey. Although the second inquiry was not as well organised as the first one, it is useful to utilise the data in order to assess how the method proposed here works in an African situation.

The estimates of real fluctuations and age distributions for Malawi's males and females are shown in Table 6.7 and Figure 6.2. It is worthy of note that the estimates derived for young ages (up to age 25) for males and females are close. In addition, the patterns of the estimates for the two sexes as shown in Figure 6.2 are strikingly similar.

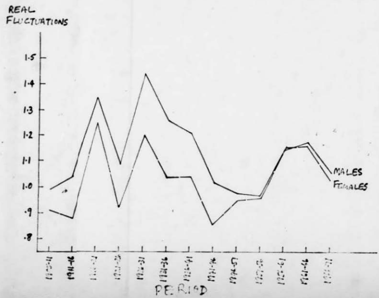
For both sexes, the pattern of the estimated fluctuations points to decreased birth rates from 1921 to 1926 relative to the preceding periods, followed by a rise between 1926 and 1931. The period 1931 to 1946 shows a steady fall in birth rates followed by an increase from 1946 to 1966 and then a decline in the 1966-71 period. This pattern is also reflected in the estimated age distributions. The remarkable similarity between the males and females estimated seems to be a measure of high

TABLE 6.7: Results from the Period-Age Interval Method for Malawi at Surveys of 1966 and 1971

Age Group	REPORTED 1966	REPORTED 1971	SMOOTH STRUCTURE	REAL FLUCTUATIONS	TRUE DISTRIBUTIONS 1966	TRUE DISTRIBUTIONS 1971
MALES	1	2	3	4	5	6
0-4	19.14	17.28	17.94	1.055	18.68	17.07
5-9	15.45	15.80	13.88	1.168	14.13	14.64
10-14	11.37	13.42	11.94	1.143	10.30	12.31
15-19	10.02	9.94	10.42	.968	9.05	9.10
20-24	7.11	6.81	8.92	.975	8.08	7.85
25-29	6.68	5.60	7.57	1.017	8.18	6.95
30-34	5.27	5.06	6.41	1.212	7.21	7.01
35-39	5.57	4.89	5.41	1.262	6.92	6.16
40-44	3.64	4.82	4.52	1.435	4.37	5.86
45-49	4.36	3.50	3.71	1.085	4.47	3.64
50-54	2.89	3.74	2.97	1.351	3.02	3.62
55-59	2.49	2.63	2.29	1.042	2.01	2.16
60+	6.02	6.49	4.02	0.988	3.58	3.63
TOTAL	100.01	99.98	100.00	--	100.00	100.00

Age Group	REPORTED 1966	REPORTED 1971	SMOOTH STRUCTURE	REAL FLUCTUATIONS	TRUE DISTRIBUTIONS 1966	TRUE DISTRIBUTIONS 1971
FEMALES	7	8	9	10	11	12
0-4	17.97	15.86	16.89	1.019	18.76	16.60
5-9	14.20	14.29	13.40	1.155	14.82	14.91
10-14	9.94	11.96	11.67	1.150	10.72	12.94
15-19	9.87	9.96	10.30	.955	9.37	9.48
20-24	8.39	9.26	8.93	.946	7.37	8.15
25-29	8.20	6.75	7.67	.858	7.68	6.34
30-34	6.20	6.22	6.58	1.041	6.56	6.60
35-39	6.28	5.43	5.62	1.036	6.48	5.61
40-44	4.01	5.21	4.75	1.200	4.22	5.49
45-49	4.61	3.41	3.96	.923	4.76	3.53
50-54	2.72	3.85	3.21	1.249	2.72	3.87
55-59	2.31	2.23	2.51	.882	2.20	2.13
60+	5.30	5.56	4.51	.913	4.34	4.35
TOTAL	100.00	99.99	100.00	--	100.00	100.00

Figure 6.2: Estimated Pattern of real fluctuations in Malawi between 1905 and 1971



consistency of the results by the method. However, because of three factors it is very difficult to determine the degree of plausibility of the estimates on Malawi : first, the Malawi 1966 census is believed to have been better conducted than the National sample survey of 1971-72, and thus the patterns of age and coverage errors at the two surveys were probably different, contrary to the assumptions of our method; second, unlike the results from the Turkish censuses, it is not possible to compare the results of the 1966 and 1971 surveys with estimates from earlier surveys in order to ascertain the consistency of the results; thirdly, Malawi had a big proportion of the male population outside the country as labour migrants in Southern Africa at the time of the two surveys. Nevertheless, the estimates for younger ages look plausible.

6.4. The method extended to use ten-year inter-censal data

Very few countries in the developing (or even developed) world are as fortunate as Turkey in having quinquennial censuses. Many developing countries have conducted censuses at an interval of ten years, and the form of the method described above can be applied to decennial censuses and data by ten year age groups. With the same calculations as in Table 6.1, the method is applied to the ten year group age data of decennial censuses of Fiji, Ghana, Mexico and Mauritius. The results given in Table 6.9 will be discussed later in the section. However, for the purpose of tracing birth and/or migration fluctuations, a ten year unit is a broad and gross measure. Methods of splitting the ten into five year age group estimates have been considered elsewhere [1], but they depend on

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1. For instance, splitting methods were suggested by Carrier, N.H. and Farrag , A.M. in their paper: 'The Reduction of Errors in Census Populations for Statistically Underdeveloped Countries'. Population Studies, XIII. 3 (March 1959).

smoothness assumptions which would be contrary to the present purpose. In order to estimate a true age structure in five year groups, of decennial censuses, a suitable extension of the method is suggested below.

(a) Using five year age groups of Decennial censuses

Let us, as before, consider reported age distributions of censuses A and B.

Ten year age group	Census A	Census B
1	$A_1^1 = S_1^1(1+\lambda_1^1)(1+\epsilon_1^1)$	$B_1^1 = S_1^1(1+\lambda^*)(1+\lambda)(1+\epsilon_1^1)$
	$A_1^2 = S_1^2(1+\lambda_1^2)(1+\epsilon_1^2)$	$B_1^2 = S_1^2(1-\lambda^*)(1+\lambda)(1+\epsilon_1^2)$
2	$A_2^1 = S_2^1(1+\lambda_2^1)(1+\epsilon_2^1)$	$B_2^1 = S_2^1(1+\lambda_1^1)(1+\epsilon_2^1)$
	$A_2^2 = S_2^2(1+\lambda_2^2)(1+\epsilon_2^2)$	$B_2^2 = S_2^2(1+\lambda_1^2)(1+\epsilon_2^2)$
.	.	.
.	.	. .....(6.7)
.	.	.
n	$A_n^1 = S_n^1(1+\lambda_n^1)(1+\epsilon_n^1)$	$B_n^1 = S_n^1(1+\lambda_{n-1}^1)(1+\epsilon_n^1)$
	$A_n^2 = S_n^2(1+\lambda_n^2)(1+\epsilon_n^2)$	$B_n^2 = S_n^2(1+\lambda_{n-1}^2)(1+\epsilon_n^2)$

where we are retaining $(1+\lambda)$ as the first ten year birth fluctuation allowance and introducing $(1+\lambda^*)$ and $(1-\lambda^*)$ to describe the deviations in the five year groups from the $1+\lambda$. Superscripts 1 and 2 refer to five year cohorts 1 and 2 of a ten year age group indicated by a subscript. Other notations are the same as in Section 6.2.

Now:

$$R_1^1 = A_1^1/B_1^1 = \frac{1+\lambda_1^1}{(1+\lambda^*)(1+\lambda)}$$

$$R_2^1 = A_2^1/B_2^1 = \frac{1+\lambda_2^1}{1+\lambda_1^1}$$

$$\vdots$$

$$R_n^1 = A_n^1/B_n^1 = \frac{1+\lambda_n^1}{1+\lambda_{n-1}^1} \quad \text{........(6.8)}$$

Similarly:

$$R_1^{(2)} = \frac{1+\lambda_1^{(2)}}{1+(1-\lambda^*)(1+\lambda)}$$

$$R_2^{(2)} = \frac{(1+\lambda_2^{(2)})}{(1+\lambda_1^{(2)})}$$

$$\vdots \qquad\qquad \vdots \qquad\qquad \ldots\ldots.(6.9)$$

$$R_n^{(2)} = \frac{1+\lambda_n^{(2)}}{1+\lambda_{n-1}}$$

Successive multiplication of R_i's gives:

$$\pi_1^1 = R_1^1 = \frac{1+\lambda_1^1}{(1+\lambda^*)(1+\lambda)}$$

$$\pi_2^1 = R_1^1 . R_2^1 = \frac{1+\lambda_2^1}{(1+\lambda^*)(1+\lambda)}$$

$$\vdots \qquad\qquad \vdots \qquad\qquad \ldots\ldots.(6.10)$$

$$\pi_n^1 = R_1^1 . R_2^1 \ldots\ldots R_n^1 = \frac{1+\lambda_n^1}{(1+\lambda^*)(1+\lambda)}$$

Hence

$$(1+\lambda_1^1) = \pi_1^1(1+\lambda^*)(1+\lambda)$$

$$(1+\lambda_2^1) = \pi_2^1(1+\lambda^*)(1+\lambda)$$

$$\vdots \qquad\qquad \vdots \qquad\qquad \ldots\ldots.(6.11)$$

$$(1+\lambda_n^1) = \pi_n^1(1+\lambda^*)(1+\lambda)$$

Likewise

$$\pi_1^{(2)} = \frac{1+\lambda_1^{(2)}}{(1-\lambda^*)(1+\lambda)}$$

$$\pi_2^{(2)} = \frac{1+\lambda_2^{(2)}}{(1-\lambda^*)(1+\lambda)}$$

$$\vdots \qquad\qquad \vdots \qquad\qquad \ldots\ldots.(6.12)$$

$$\pi_n^{(2)} = \frac{(1+\lambda_n^{(2)})}{(1-\lambda^*)(1+\lambda)}$$

and

$$1+\lambda_1^{(2)} = \pi_1^{(2)}(1-\lambda^*)(1+\lambda)$$

$$1+\lambda_2^{(2)} = \pi_2^{(2)}(1-\lambda^*)(1+\lambda)$$

$$\vdots \qquad\qquad \vdots$$

$$(1+\lambda_n^{(2)}) = \pi_n^{(2)}(1-\lambda^*)(1+\lambda) \qquad \ldots\ldots.(6.13)$$

Summing up $(1+\lambda_i^j)$ we get:

$$\sum_{i=1}^{n} (1+\lambda_i^1) = (1+\lambda^*)(1+\lambda)\sum_{i=1}^{n} \pi_i^1 \qquad \ldots\ldots.(6.14)$$

and

$$\sum_{i=1}^{n} (1+\lambda_i^{(2)}) = (1-\lambda^*)(1+\lambda)\sum_{i=1}^{n} \pi_i^{(2)} \qquad \ldots\ldots.(6.15)$$

By assuming that the true fluctuations are unsystematic over time with the result that $\sum_{i=1}^{n} \lambda_i^{(1)}$ and $\sum_{i=1}^{n} \lambda_i^{(2)}$ are very small compared with $\Sigma(1)$, we equate equations (6.14) and (6.15):

$$(1+\lambda^*)(1+\lambda) \sum_{1}^{n} \pi_i^{(1)} = (1-\lambda^*)(1+\lambda) \sum_{1}^{n} \pi_i^{(2)} \qquad \ldots\ldots.(6.16)$$

The $(1+\lambda)$ cancels to give the solution of λ^* and hence, the estimated true age distribution is obtained as before.

(b) Applying the Extended Method to Empirical data

The procedure for calculating $1+\lambda_i^j$ from the extended method is illustrated in Table 6.8, where it is applied to Ghana female data of 1960 and 1970 censuses. The computations are basically the same as in the period-age interval method (in Table 6.1), except that care has to be taken in the chaining of two different cohorts (R_i^j) separately in order to find π_i^j 's and $1+\lambda_i^j$'s. Furthermore, the extended method has been applied to a variety of age data from different regions of the developing world. The countries whose data have been used are Ghana, Mauritius and

TABLE 6.8: <u>Computational Procedure of the Extended Method - Applied to Ghana Females 1960-70</u>

Age Group	i	j	REPORTED A_i^j 1960	REPORTED B_i^j 1970	$R_i^j = \frac{A_i^j}{B_i^j}$	π_i^j	$1+\lambda_i^j$ where $1+\lambda = .990$ $1+\lambda^* = .90414$ $1-\lambda^* = 1.09586$	Smooth Structure S_i^j	Provisional True Structure 1960	Provisional True Structure 1970	Final True Structure 1960	Final True Structure 1970
			1	2	3	4	5	6	7	8	9	10
0-4	} 1	1	19.67	18.21	1.0802	1.0802	.9668	18.71	18.09	16.55	18.22	17.14
5-9		2	15.12	16.74	.9032	.9032	.9799	15.01	14.71	16.29	15.31	16.87
10-14	} 2	1	9.72	11.32	.8587	.9275	.8302	12.58	10.44	12.17	10.86	12.60
15-19		2	7.98	8.79	.9078	.8200	.8896	10.61	9.43	10.40	9.81	10.77
20-24	} 3	1	9.70	8.71	1.1137	1.0329	.9246	8.86	8.19	7.36	8.52	7.62
25-29		2	9.21	7.92	1.1629	.9536	1.0346	7.35	7.60	6.53	7.91	6.76
30-34	} 4	1	7.39	6.88	1.0741	1.1095	.9931	6.09	6.05	5.63	6.29	5.83
35-39		2	5.39	5.03	1.0716	1.0218	1.1086	5.03	5.57	5.21	5.80	5.40
40-44	} 5	1	4.38	4.07	1.0762	1.1940	1.0687	4.12	4.41	4.09	4.58	4.24
45-49		2	2.87	2.97	.9663	.9874	1.0712	3.33	3.56	3.69	3.71	3.82
50-54	} 6	1	2.46	2.59	.9498	1.1341	1.0151	2.64	2.68	2.82	2.79	2.92
55-59		2	1.46	1.53	.9542	.9422	1.0222	2.04	2.09	2.19	2.17	2.27
60-64	} 7	1	1.64	1.65	.9939	1.1272	1.0089	1.50	1.51	1.52	1.58	1.57
65-69		2	.86	1.08	.7963	.7503	.8140	1.02	.83	1.04	.87	1.08
70-74	} 8	1	.80	.94	.8511	.9593	.8587	.63	.54	.63	.57	.65
75-79		2	.44	.48	.9167	.6878	.7462	.32	.24	.26	.25	.27
80+			.91	1.09	--	--	--	.17	.17	.17	.18	.18
TOTAL			100.00	100.00	--	--	--	100.00	96.11	96.55	100.02	99.99

TABLE 6.9: Comparing Real Fluctuations for Five and Ten-Year Age Groups from Decennial Censuses - Female Populations

Age Group	FIJI ISLANDS 1956-66		GHANA 1960-70		ISLAND OF MAURITIUS 1962-72		MEXICO 1960-70		UGANDA 1959-69	
	5-year	10-year	5-year	10-year	5-year	10-year	5-year	10-year	5-year	10-year
0-4	.927	.992	.895	.990	.869	1.026	.952	.989	1.091	.993
5-9	1.057		1.085		1.183		1.026		.895	
10-14	.989	.998	.967	.984	1.168	1.231	.932	.956	.960	.863
15-19	1.006		.980		1.273		.979		.765	
20-24	.964	.984	.830	.866	1.180	1.089	.876	.912	.914	.856
25-29	1.005		.890		.952		.949		.798	
30-34	.944	.965	.925	.985	.856	.910	.889	.949	1.031	.948
35-39	.989		1.035		.949		1.022		.867	
40-44	.962	1.006	.993	1.056	.935	1.039	.977	1.018	1.225	1.158
45-49	1.057		1.109		1.133		1.066		1.092	
50-54	1.005	.956	1.069	1.088	.963	.992	.955	1.036	1.575	1.484
55-59	.898		1.071		.998		1.139		1.395	
60-64	.845	.856	1.015	1.031	.942	.931	1.178	1.197	1.503	1.580
65-69	.873		1.022		.898		1.220		1.759	
70-74	1.004	1.014	1.009	.945	.918	.908	1.301	1.173	1.255	1.332
75-79	1.027		.814		.875		.998		1.507	

Uganda from Africa; the Fiji Islands from Oceania; Mexico from Latin America and Turkey from Southern Europe and Western Asia. The results from the applications are shown in Tables 6.9 to 6.17 and are discussed below.

GHANA:

The application of the extended method to Ghana's data is shown in the example for females (Table 6.8) and other results of the applications are in Tables 6.9, 6.10 and 6.11 . As can be seen from Table 6.9, the estimates of $(1+\lambda_i)$ in ten year age groups are bigger for the 1960-70 than for the 1950-60 decade of births and for the 1950-60 decade than 1940-50. This could imply that the birth rates increased over the 1940-70 period in Ghana. However, on the basis of five year age groups, Table 6.9 shows erratic estimates, indicating smaller birth rates for cohorts 1945-50, 1955-60 and 1965-70 than for the adjacent five year periods. While it is possible for birth rates in Ghana to have increased and decreased in alternate five year periods due to irregular influences in the past, more plausible explanation is probably given by one or more of the following factors. Firstly, at least for the 1960-70 decade, the big difference between the political climates of the 1960-65 and 1966-70 periods may have led to real variations in the birth rates. The big upwards fluctuations estimated for the period 1960-65 (1.085) relative to 1965-70 period estimate (0.895) is, perhaps, a true reflection of what happened in Ghana in 1960-65 when Kwame Nkrumah was leading a strong, confident and stable government and in 1966-70 when there was a disturbed situation consequent on military rule after the coup against the civilian government. Secondly, it is possible that a spurious saw-tooth effect has been introduced by the way the method has been extended. The assumption that the overall deviations in the summed series are small may be invalid.

TABLE 6.10: <u>The Reported and Estimated Age Distributions by the Extended Method for Ghana</u>

Age Group	1960				1970			
	MALES		FEMALES		MALES		FEMALES	
	Reported	Estimated	Reported	Estimated	Reported	Estimated	Reported	Estimated
0-4	18.89	17.78	19.67	18.82	18.32	16.65	18.21	17.14
5-9	15.16	15.00	15.12	15.31	17.14	16.37	16.74	16.87
10-14	10.52	10.15	9.72	10.86	12.11	11.29	11.32	12.60
15-19	8.10	9.35	7.98	9.81	9.39	10.47	8.79	10.77
20-24	7.89	8.02	9.70	8.52	7.19	7.05	8.71	7.62
25-29	8.19	7.86	9.21	7.91	6.83	6.33	7.92	6.76
30-34	7.13	6.39	7.39	6.29	6.21	5.38	6.83	5.83
35-39	5.83	6.07	5.39	5.80	5.21	5.24	5.03	5.40
40-44	4.88	5.16	4.38	4.58	4.11	4.20	4.07	4.24
45-49	3.61	4.30	2.87	3.71	3.39	3.90	2.97	3.82
50-54	2.85	3.34	2.46	2.79	2.82	3.18	2.59	2.92
55-59	1.74	2.50	1.46	2.17	1.80	2.50	1.53	2.27
60-64	1.87	1.93	1.64	1.58	1.77	1.76	1.65	1.57
65-69	.95	1.02	.86	.87	1.12	1.15	1.08	1.08
70-74	.88	.68	.80	.57	.99	.75	.94	.65
75-79	.48	.28	.44	.25	.51	.29	.48	.27
80+	1.03	.17	.91	.18	1.09	.16	1.14	.18
TOTAL	100.00	100.00	100.00	100.02	100.00	100.00	100.00	99.99

TABLE 6.11: A comparison of the corrected Age distributions obtained by the application of the Extended Method and Demeny-Shorter (D-S) method to female population data of the 1960 and 1970 censuses of Ghana

Age Group	1960 Extended Method	1960 D-S Method	1970 Extended Method	1970 D-S Method
0-4	18.82	18.64	17.14	17.16
5-9	15.31	14.33	16.87	15.78
10-14	10.86	10.91	12.60	12.66
15-19	9.81	9.46	10.77	10.36
20-24	8.52	8.79	7.62	7.85
25-29	7.91	7.80	6.76	6.68
30-34	6.29	6.64	5.83	6.15
35-39	5.80	5.85	5.40	5.43
40-44	4.58	4.93	4.24	4.57
45-49	3.71	3.83	3.82	3.93
50-54	2.79	3.05	2.92	3.20
55-59	2.17	2.25	2.27	2.35
60-64	1.58	1.73	1.57	1.73
65-69	.87	.90	1.08	1.13
70-74	.57	.62	.65	.72
75+	.43	.27	.42	.30
TOTAL	100.00	100.02	99.99	100.00

A substantial error in this assumption could give the characteristics found. Thirdly, the imbalanced effects due to digit preference (already discussed in Chapter 2) between series of age groups 0-4, 10-14, etc., on one hand and 5-9, 15-19, etc., on the other, might have by changes between censuses, injected a further saw-tooth deviation. Fourthly, the large scale expulsion of aliens by the Ghanaian government in the late 1960's has a distorting effect on the 1970 original census data, which is not adjusted for because of lack of the requisite information. It seems likely that this accounts for much of the apparent downward fluctuation for the 1940-50 birth cohort. It should be noted, however, that deviations caused by migration effects which persist from 1960-70 are real fluctuation and properly form part of the λ_i .

However, it is noteworthy that the true percent age distributions estimated by the extended method for Ghana show a plausible picture. As can be seen from Table 6.10, the patterns of the corrected age distributions for males and females in 1960 and 1970 are more regular than the reported distributions. Furthermore, a comparison of the distributions estimated by the extended method and the Demeny-Shorter technique (see Table 6.11) shows that the results for Ghana females from the two methods are close both in level and pattern. This close agreement is partly the result of the similar assumption about age and residual coverage errors. Nevertheless, it illustrates that the simpler procedure which eliminates the assumption about constancy of overall coverage and the need to estimate mortality can work equally well.

UGANDA:

The results of the application of the extended method to Uganda data of 1959[1] and 1969 censuses are shown in Tables 6.9, 6.12 and 6.13. The estimates of the real fluctuations for ten-year age groups shown in

1. The footnote on page 123 equally applies here, namely that the results of the application of the Demeny-Shorter and the extended methods are affected by the bias arising from the use of the interpolated data of the Uganda 1959 census.

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TABLE 6.12: The Reported and Estimated Age Distributions by the Extended Method for Uganda

Age Group	1959				1969			
	MALES		FEMALES		MALES		FEMALES	
	Reported	Estimated	Reported	Estimated	Reported	Estimated	Reported	Estimated
0-4	17.33	17.54	17.37	17.56	18.96	19.50	19.74	20.19
5-9	13.68	12.49	13.30	11.21	15.33	14.21	15.57	13.28
10-14	10.62	10.41	10.50	11.28	11.91	11.86	11.04	12.00
15-19	8.71	9.04	9.16	8.37	8.62	9.09	8.77	8.10
20-24	8.00	8.45	9.12	9.06	7.02	7.53	8.08	8.12
25-29	7.97	6.87	8.75	6.34	7.31	6.40	8.06	5.91
30-34	7.16	6.61	7.54	7.47	6.33	5.93	6.34	6.35
35-39	6.30	5.53	6.35	5.51	5.38	4.79	5.04	4.44
40-44	5.47	5.95	5.23	6.53	4.12	4.55	4.07	5.14
45-49	4.60	4.79	4.05	4.70	3.52	3.72	3.17	3.72
50-54	3.52	4.31	2.93	4.02	3.10	3.86	3.07	4.26
55-59	2.47	3.51	2.18	3.62	2.03	2.93	1.73	2.90
60-64	1.85	2.13	1.62	1.90	2.06	2.42	1.94	2.31
65-69	1.08	1.44	.90	1.55	1.29	1.74	1.05	1.83
70-74	.68	.51	.53	.42	1.15	.87	.98	.80
75-79	.34	.26	.28	.31	.58	.44	.44	.50
80+	.22	.16	.19	.15	1.29	.16	.91	.15
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 6.13: Comparison of the corrected age distributions obtained by the application of the Extended Method and the Demeny-Shorter (D-S) method to female population data of the 1959 and 1969 Uganda Census

Age Group	1959 Extended Method	1959 D-S Method	1969 Extended Method	1969 D-S Method
0-4	17.56	18.50	20.19	21.05
5-9	11.21	14.17	13.28	16.61
10-14	11.28	11.19	12.00	11.80
15-19	8.37	9.79	8.10	9.37
20-24	9.06	8.33	8.12	7.39
25-29	6.34	6.90	5.91	6.36
30-34	7.47	6.37	6.35	5.38
35-39	5.51	5.56	4.44	4.44
40-44	6.53	5.25	5.14	4.06
45-49	4.70	4.45	3.72	3.50
50-54	4.02	3.02	4.26	3.18
55-59	3.62	3.26	2.90	2.60
60-64	1.90	1.37	2.31	1.66
65-69	1.55	1.37	1.83	1.60
70-74	.42	.31	.80	.58
75+	.46	.16	.65	.43
TOTAL	100.00	100.00	100.00	100.01

Table 6.9 indicate three basic phases: a phase of big cohorts relative to population growth from 1889 to 1929, followed by a period of sharply reduced birth rates from 1929 to 1959 and then a much recovered birth rate in the 1959 to 1969 period. A basically similar pattern of past birth cohorts is maintained by the estimates for the five year age groups.

It is clear that these estimates in Table 6.9 are not representative of the past birth rates in Uganda. For instance, the events of the 1950s, namely, improved medical services, a booming economy due to the high coffee and cotton prices, and the political stability despite the exile of the Kabaka of Buganda (1954-5), are not consistent with a lowered birth rate followed by a sharp increase. Besides, there is no reason to suppose that the pre-1930 period was characterized by the immensely high birth rates implied, although knowledge about demographic history of Uganda before 1930s is shaky. It is clear that the estimates have been dominated by the influence of large-scale migrations to Uganda in the 1950s and 60s, especially the political refugees from Rwanda and Zaire. The differentials in coverage between the 1959 and 1969 censuses were appreciable - the 1959 census did not cover all the parts of Uganda and was less sophisticated than the 1969 census. Differential coverage by age at the two censuses might have had an effect additional to migration. Migration changes could not be adjusted for because of lack of the requisite data.

The corrected percent age distributions for Uganda are shown in Tables 6.12 and 6.13. It can be seen from Table 6.12 that the pattern of the corrected distributions is irregular, a reflection of the estimated real fluctuations in Table 6.9. This irregularity is displayed more clearly in Table 6.13 where age distributions of female populations from the extended method are compared with the more regular estimated distributions from the Demeny-Shorter approach. It is difficult to find out which of the two methods produces the more plausible estimates, because of the lack of sufficient knowledge about the demographic past in Uganda, but the Demeny-Shorter results are the more plausible. Since several of the assumptions of both approaches are seriously contradicted, no clear conclusions can be drawn.

FIJI ISLANDS, ISLAND OF MAURITIUS AND MEXICO

The results from the application of the extended method on the Fiji Islands, the Island of Mauritius and Mexico are given in Tables 6.9, 6.14, 6.15 and 6.16. The estimates of real fluctuations, especially the ten year estimates, for the Fiji Islands in Table 6.9, show a fairly constant level of adjustment since the early twentieth century, with minor fluctuations displayed in the five year age groups. Other evidence suggests that birth rates had been relatively constant in Fiji for many years prior to 1965. In addition, Table 6.9 shows ten year estimates for Mexico which indicate a gradual general increase in fertility between 1940 and 1970. The former date is preceded by progressively higher estimates, indicating a gradual fall of birth rates. This ten year age group trend of birth rates is slightly broken by small deviations shown in the five year age group estimates. As in Uganda, the trough for the years 20 to 40 before the survey are likely to be due to migration. The values for the twenty years before 1970 suggest a relatively constant birth rate. Table 6.9 also shows estimates for the Island of Mauritius which reflect the drastic fall in fertility levels, in accord with the study of Xenos (1976). A combination of increasing age at marriage and the success of the family planning programme in the Island led to a falling birth rate with a sharp drop in 1967-72. It is particularly notable that for this country (where the census accuracy is believed to be good, although there is some migration which has not been allowed for) that

TABLE 6.14: Reported and Estimated age distributions by the Extended Method for the Fiji Islands

Age Group	1956				1966			
	MALES		FEMALES		MALES		FEMALES	
	Reported	Estimated	Reported	Estimated	Reported	Estimated	Reported	Estimated
0-4	17.77	17.70	18.51	17.64	17.28	17.28	17.34	16.54
5-9	14.97	14.07	15.44	14.82	16.23	15.31	16.23	15.60
10-14	12.60	11.90	12.95	12.03	13.15	12.45	13.28	12.35
15-19	10.27	9.96	10.87	10.64	10.50	10.22	10.88	10.67
20-24	8.49	8.55	8.84	8.44	8.52	8.60	9.03	8.63
25-29	7.11	7.19	7.25	7.43	7.03	7.13	7.37	7.57
30-34	5.70	5.95	5.84	6.07	5.79	6.06	5.73	5.96
35-39	5.22	5.37	5.24	5.58	4.93	5.09	4.90	5.22
40-44	4.36	4.56	4.06	4.41	3.99	4.19	3.89	4.23
45-49	3.34	3.39	2.93	3.26	3.64	3.71	3.45	3.84
50-54	2.40	2.52	2.23	2.50	2.92	3.08	2.65	2.98
55-59	1.94	2.20	1.72	2.06	1.93	2.20	1.77	2.12
60-64	2.08	2.19	1.58	1.82	1.45	1.53	1.33	1.54
65-69	1.50	1.85	1.00	1.34	.98	1.21	.85	1.14
70-74	1.07	1.57	.75	1.13	.68	1.02	.57	.86
75-79	.54	.77	.38	.56	.46	.66	.33	.48
80+	.64	.26	.41	.27	.52	.26	.40	.27
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 6.15: The Reported and Estimated age distributions by the Extended Method for Mexico

Age Group	1960 MALES Reported	1960 MALES Estimated	1960 FEMALES Reported	1960 FEMALES Estimated	1970 MALES Reported	1970 MALES Estimated	1970 FEMALES Reported	1970 FEMALES Estimated
0-4	16.92	16.71	16.27	16.78	17.25	17.09	16.62	17.19
5-9	15.60	14.50	14.96	14.58	16.35	15.24	15.68	15.32
10-14	12.88	11.08	12.16	11.00	13.59	11.73	12.94	11.74
15-19	10.02	10.08	10.29	10.08	10.35	10.45	10.61	10.43
20-24	8.10	8.01	8.83	7.95	8.02	7.96	8.70	7.85
25-29	6.89	7.53	7.50	7.66	6.55	7.19	6.97	7.13
30-34	5.82	6.16	5.97	6.14	5.34	5.67	5.43	5.60
35-39	5.53	5.70	5.51	5.60	5.13	5.31	5.28	5.38
40-44	3.89	4.19	3.94	4.18	3.99	4.31	4.03	4.29
45-49	3.52	4.00	3.57	4.11	3.45	3.93	3.34	3.85
50-54	3.04	3.50	3.07	3.47	2.45	2.83	2.49	2.82
55-59	2.34	2.93	2.26	2.87	2.08	2.60	2.11	2.69
60-64	2.14	2.46	2.13	2.36	1.87	2.15	1.93	2.15
65-69	1.17	1.32	1.21	1.32	1.44	1.63	1.48	1.62
70-74	.93	1.06	.99	1.12	1.01	1.16	1.02	1.16
75-79	.53	.50	.55	.50	.50	.48	.55	.50
80+	.68	.27	.79	.28	.63	.27	.82	.28
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

the known birth rate trends for the twenty five years up to 1972 are so clearly discernible.

The age distributions estimated by the extended method for the Fiji Islands and Mexico are shown in Tables 6.14 and 6.15. Both Tables show that the estimated distributions are regular and probably plausible, mainly because the censuses of these countries were of fair quality.

(c) Consistency of the extended method

It is important to examine the consistency of the results from the extended method by comparing them with information from other sources. Since fairly reliable vital registration systems have been present for some time in the Fiji Islands, the Island of Mauritius and Mexico, we shall use the estimates in Table 6.9 to splice the arithmetic average of annual birth rates over the intercensal period into two birth rates representing five year periods. The birth rates obtained are shown, together with the vital registration rates, in Table 6.16. It is encouraging to note the very close agreement between our estimates and vital registration estimates. This comparison gives convincing evidence that the extended method can yield quite plausible estimates of the pattern of fertility for at least the ten year period preceding the latest census.

Another measure of consistency of the extended method estimates is displayed in Table 6.17. The period-age interval method and the extended method were used to derive estimates of real fluctuations for Turkish females before 1960. To do this, the period-age interval method was applied to the 1955 and 1960 census data, while the extended method used the 1950 and 1960 census data. It is remarkable that, notwithstanding the slight differences in level, the estimates in Table 6.17 show a strikingly similar pattern of real fluctuations. For example, both sets

TABLE 6.16: Birth Rates per 1000 calculated by the Extended Method, compared with those from Birth Registration

	FIJI ISLANDS		ISLAND OF MAURITIUS		MEXICO	
	1956-61	1961-66	1962-67	1967-72	1960-64	1965-69
Birth Registration	40.8 [1]	37.8 [1]	36.5 [2]	27.4 [2]	44.4 [3]	43.2 [3]
Extended Method	41.9	36.7	36.8	27.0	45.4	42.2

Sources: 1. U.N. Demographic Year Book, 1969

2. C. Xenos, Fertility Change in Mauritius and the Impact of the Family Planning Programme, 1976.

3. Population Index, July 1974, page 597.

TABLE 6.17: Comparing Estimates derived by the Period-Age Interval Method and Extended Method from Turkish Females, 1955-60 and 1950-60

Age Group	Period-Age Interval Method 1955-60 data	Extended Method 1950-60 data
0-4	.994	1.009
5-9	1.032	.981
10-14	.960	.955
15-19	.808	.821
20-24	.954	.905
25-29	1.079	1.134
30-34	1.077	1.019
35-39	.918	.945
40-44	.799	.797
45-49	1.038	1.067
50-54	1.129	1.129
55-59	1.176	1.241
60-64	1.129	1.194
65-69	1.089	1.140
70-74	1.012	1.215
75-79	1.019	1.076

of estimates show a marked fall in the relative birth cohorts in the war periods and increases in the inter-war periods.

6.5. Extension of the method to use single year age distributions

Sometimes, corrections for individual years of age are desirable at earlier ages to aid studies of trends in fertility. In the present section, an extension of the method described in Section 6.2 is devised to estimate real fluctuations and age distributions at single years of age. The calculations can be made in slightly different ways.

(a) First approach

For, say, a five year census interval and one year age groups, the method as considered in Section 6.4 extends naturally to give:

$$(1+\lambda_i^{(h)}) = \pi_i^{(h)}(1+\lambda^{(h)})(1+\lambda) \; * \qquad \text{.......(6.17)}$$

where $h = 1, 2, 3, 4, 5$ for single years in the i^{th} group.

Then:

$$\sum_i (1+\lambda_i^{(h)}) = (1+\lambda)(1+\lambda^{(h)}) \sum_i \pi_i^{(h)}$$

$$= C(1+\lambda) \qquad \text{.......(6.18)}$$

where C is the same for all h.

In this derivation, the deviations, $\lambda^{(h)}$, are assumed to add to zero over the first five year age group, that is, no allowance is made for weighting the numbers at each individual year.

Thus,

$$(1+\lambda^{(h)}) = \frac{C}{\sum_i \pi_i^{(h)}}$$

and

$$\sum_h (1+\lambda^{(h)}) = 5$$

$$\therefore \quad C \sum_h \frac{1}{\sum_i \pi_i^{(h)}} = 5 \qquad \text{.......(6.19)}$$

We can now solve for C and $\lambda^{(h)}$ and hence $\lambda_i^{(h)}$.

* Note that $\lambda^{(h)}$ are considered as deviations after allowance for the overall fluctuation λ in the first age group.

(b) Second Approach

As an alternative to the first approach, we may follow the same procedure exactly as in the extended method of Section 6.4 to break down five or ten year grouping into single years' real fluctuations according to the census interval. In this case the assumption of equal weighting for the individual years in the group is dropped.

Using the notations as before, but with superscripts like $\lambda^{(h)}$ when h goes from 1 to 5 or 1 to 10:

$$A_1^{(h)} = s_1^{(h)}(1+\lambda_1^{(h)})(1+\epsilon_1^{(h)})$$

$$B_1^{(h)} = s_1^{(h)}(1+\lambda^{(h)})(1+\epsilon_1^{(h)}) \quad \text{etc..} \qquad \text{.......(6.20)}$$

leads to the equation:

$$\sum_i (1+\lambda_i^{(h)}) = (1+\lambda^{(h)})\sum_i \pi_i^{(h)} = C^{*} \qquad \text{.......(6.21)}$$

for all h because it is assumed that the $\sum_i (1+\lambda_i^{(h)})$ are all equal for the same reasons as seen before in the first approach.

The extra equation needed is:

$$\sum_h (1+\lambda^{(h)}) = N(1+\lambda) \qquad \text{.......(6.22)}$$

where λ represents the N(5 or 10) year birth fluctuation as calculated by the method given in Section 6.2.

If we write $\sum_i \pi_i^{(h)} = \alpha_h$

then

$$1+\lambda^{(h)} = \frac{\alpha_1}{\alpha_h}(1+\lambda^{(1)}) \qquad \text{.......(6.23)}$$

and

$$\sum_h (1+\lambda^{(h)}) = \frac{\alpha_1}{\alpha_1}(1+\lambda^{(1)}) + \frac{\alpha_1}{\alpha_2}(1+\lambda^{(1)}) + \frac{\alpha_1}{\alpha_3}(1+\lambda^{(1)}) + \ldots \ldots + \frac{\alpha_1}{\alpha_N}(1+\lambda^{(1)}) \qquad \text{.......(6.24)}$$

$$\therefore \; N(1+\lambda) = (1+\lambda^{(1)})\left(1+\frac{\alpha_1}{\alpha_2}+\frac{\alpha_1}{\alpha_3}+\ldots\ldots+\frac{\alpha_1}{\alpha_N}\right) \qquad \text{.......(6.25)}$$

* C is the same for all h on the assumption that fluctuations cancel out over the whole age range for each of the sets.

Since $(1+\lambda)$ can be found by the method in Section 6.2, equation 6.25 gives the solution for $(1+\lambda^{(b)})$. Hence, $1+\lambda^{(b)}$ can be obtained from equation 6.23, and $1+\lambda_i^{(b)}$ can be computed from equation 6.17 as in Section 6.5(a).

(c) Applying the two approaches to empirical data

The above two approaches described in Sections 6.5(a) and 6.5(b) have been applied to Turkish female data from the 1965 and 1970 censuses. The results obtained are shown in Table 6.18. It demonstrates that the estimates derived by the two ways of calculation (in columns 1 to 10) for the same ages with exception of the $1+\lambda^{(b)}$, are identical, implying that the simpler assumption gives results that are consistent with those from the more stringent assumption. In addition, columns 11 and 12 give the arithmetic averages of individual year estimates for each five year age group. These averages in columns 11 and 12 are close to the five year estimates in column 13 derived from the same set of data by the period-age interval method. This closeness is encouraging considering that the two approaches, unlike the period-age interval method, were applied to single year data distorted by digital preference. Besides, the pattern of estimates from the two calculations is a fair reflection of Turkish demographic history. Thus $1+\lambda_4^{(b)}$ and $1+\lambda_5^{(b)}$ are all depressed estimates, indicating the low fertility levels in the 1940s because of the Second World War; and $1+\lambda_9^{(b)}$ and $1+\lambda_{10}^{(b)}$ are clearly low estimates compared with adjacent estimates, reflecting the depressing effect of the First World War (1915-20) and the Turkish War of Independence (1920-25) on fertility levels.

It seems sensible, the relative values of the $1+\lambda_i^{(b)}$ having been obtained within age groups, to adjust them to sum to the total correction $(1+\lambda_i)$ obtained for groups of the same length as the intercensal period, since the latter is based on the assumption that the total

TABLE 6.18: Estimates of Single Age Real Fluctuations derived by the two approaches of Calculations in Sections 6.5(a) and 6.5(b), applied to Turkish female data of the 1965 and 1970 censuses

Age Group in 1970	i	$1+\lambda_i^{(1)}$ 1st	$1+\lambda_i^{(1)}$ 2nd	$1+\lambda_i^{(2)}$ 1st	$1+\lambda_i^{(2)}$ 2nd	$1+\lambda_i^{(3)}$ 1st	$1+\lambda_i^{(3)}$ 2nd	$1+\lambda_i^{(4)}$ 1st	$1+\lambda_i^{(4)}$ 2nd	$1+\lambda_i^{(5)}$ 1st	$1+\lambda_i^{(5)}$ 2nd	$\frac{1}{5}\sum_{h=1}^{5}(1+\lambda_i^{(h)})$ 1st	$\frac{1}{5}\sum_{h=1}^{5}(1+\lambda_i^{(h)})$ 2nd	$1+\lambda_i$ from Period-Age Int. Method	Scaling Factors 1st	Scaling Factors 2nd
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0-4	$1+\lambda^{(h)}$	.732	.714	1.173	1.145	1.042	1.017	.926	.904	1.126	1.100	1.000	.976	.976	.9759	1.0000
5-9	1	.759	.759	1.205	1.205	1.026	1.026	.984	.984	1.044	1.045	1.004	1.004	1.003	.9992	.9992
10-14	2	.895	.895	1.196	1.196	1.004	1.004	.971	.971	.968	.968	1.007	1.007	1.020	1.0130	1.0130
15-19	3	.842	.842	.953	.953	1.017	1.017	.998	.998	.937	.937	.950	.950	.970	1.0216	1.0216
20-24	4	.756	.756	.765	.765	.881	.882	.871	.870	.823	.822	.819	.819	.837	1.0219	1.0219
25-29	5	.707	.706	.702	.702	.842	.842	.845	.845	.823	.823	.784	.784	.796	1.0158	1.0158
30-34	6	.841	.841	.742	.742	.994	.994	.889	.889	.955	.955	.884	.884	.906	1.0248	1.0248
35-39	7	.947	.947	.970	.970	1.153	1.152	1.112	1.112	.961	.961	1.028	1.028	1.040	1.0113	1.0113
40-44	8	1.015	1.015	.834	.834	.987	.987	1.000	1.000	.951	.951	.957	.957	1.010	1.0549	1.0549
45-49	9	.946	.946	.853	.853	.736	.736	.730	.730	.649	.649	.783	.783	.877	1.1202	1.1202
50-54	10	.834	.834	.572	.572	.533	.533	.630	.629	.670	.670	.648	.648	.739	1.1412	1.1412
55-59	11	1.011	1.011	.896	.896	.842	.842	.986	.986	.971	.971	.941	.941	.978	1.0391	1.0391
60-64	12	1.144	1.143	1.025	1.025	.868	.868	.839	.840	.907	.906	.956	.956	1.036	1.0831	1.0831
65-69	13	1.174	1.174	1.157	1.158	.989	.989	1.017	1.017	1.212	1.212	1.110	1.110	1.114	1.0035	1.0035

TABLE 6.19: Final estimates of single age real fluctuations derived by the two approaches in Sections 6.5(a) and 6.5(b) and the Period-Age Interval method - applied to Turkish female data of 1965 and 1970 censuses

Age Group in 1970	i	$1+\lambda_i^{(1)}$ 1st App	$1+\lambda_i^{(1)}$ 2nd App	$1+\lambda_i^{(2)}$ 1st App	$1+\lambda_i^{(2)}$ 2nd App	$1+\lambda_i^{(3)}$ 1st App	$1+\lambda_i^{(3)}$ 2nd App	$1+\lambda_i^{(4)}$ 1st App	$1+\lambda_i^{(4)}$ 2nd App	$1+\lambda_i^{(5)}$ 1st App	$1+\lambda_i^{(5)}$ 2nd App	$1+\lambda_i$ from Period-Age Int. Method
0-4	$1+\lambda^{(n)}$	.714	.714	1.145	1.145	1.017	1.017	.904	.904	1.100	1.100	.976
5-9	1	.759	.759	1.204	1.204	1.025	1.025	.983	.983	1.044	1.044	1.003
10-14	2	.907	.907	1.212	1.212	1.017	1.017	.984	.984	.981	.981	1.020
15-19	3	.861	.861	.973	.973	1.039	1.039	1.020	1.020	.957	.957	.970
20-24	4	.773	.773	.782	.782	.901	.901	.889	.889	.840	.840	.837
25-29	5	.717	.717	.713	.713	.855	.855	.858	.858	.836	.836	.796
30-34	6	.862	.862	.760	.760	1.018	1.018	.911	.911	.979	.979	.906
35-39	7	.958	.958	.981	.981	1.165	1.165	1.124	1.124	.972	.972	1.040
40-44	8	1.070	1.070	.880	.880	1.041	1.041	1.055	1.055	1.003	1.003	1.010
45-49	9	1.060	1.060	.956	.956	.824	.824	.818	.818	.927	.727	.877
50-54	10	.952	.952	.653	.653	.608	.608	.718	.718	.764	.764	.739
55-59	11	1.051	1.051	.931	.931	.875	.875	1.024	1.024	1.009	1.009	.978
60-64	12	1.239	1.239	1.110	1.110	.940	.940	.909	.909	.982	.982	1.036
65-69	13	1.178	1.178	1.162	1.162	.992	.992	1.021	1.021	1.216	1.216	1.114

TABLE 6.20: Estimates of real fluctuations derived by the second approach from ten year interval censuses of the Island of Mauritius, 1962 and 1972 - female population

i	$1+\lambda_i^{(1)}$	$1+\lambda_i^{(2)}$	$1+\lambda_i^{(3)}$	$1+\lambda_i^{(4)}$	$1+\lambda_i^{(5)}$	Extended Method in Section 6.4 $1+\lambda_i$
$1+\lambda^{(h)}$	.612	.996	.767	.911	1.059	.869
1	.761	1.248	1.277	1.176	1.454	1.183
2	.897	1.350	1.015	1.255	1.323	1.168
3	.960	1.359	1.355	1.158	1.533	1.273
4	.922	1.521	1.086	1.167	1.203	1.180
5	.783	1.018	1.107	.926	.926	.952
6	.635	.959	.811	.912	.963	.856
7	.823	1.036	1.003	.913	.970	.949
8	.750	.986	.899	1.022	1.018	.935
9	1.083	1.273	1.181	1.129	.999	1.133
10	1.137	.993	.916	.876	.894	.963
11	1.061	.911	.951	1.093	.974	.998
12	1.098	.825	.983	.853	.919	.942
13	1.010	.756	.824	.874	1.026	.898

population is correct and the former that the sub-populations are all correct.

In order to complete the splicing of the five year estimates with single year estimates, the values in columns 1 to 10 are adjusted to give averages equal to column 13. To do this, column 13 is divided by columns 11 and 12 to provide the scaling factors shown in columns 14 and 15 of Table 6.18. The scaling factors are multiplied by the respective columns 1 to 10 of Table 6.18 to give the final estimates of single year real fluctuations exhibited in Table 6.19. As can be seen in Table 6.19, the estimates of the first and second calculations are identical because the underlying relation of the two calculations to the period-age interval method is the same.

However, it is pertinent to point out that on the evidence of the application made to different age data, it appears that these two calculations may not give satisfactory results if the pattern of digital preference in age reporting is different in the two censuses used. The effect of differential digital preference on the results is shown by Table 6.20 where Mauritius ten-year census interval observations were examined. For example, it is clear from the Table that estimates of 0, 5, 10, 15, 20, etc., years ago are severely depressed relative to other estimates owing to the effect of changes in heaping on ages with digits ending in 0 and 5. It is, therefore, important that an inspection of age data be made in respect to digit preference patterns before application.

6.6. How valid are the Assumptions of the Method?

The method as described in Section 6.2 and its extensions given in Sections 6.4 and 6.5 work under three assumptions. It is important to examine the effects of these assumptions on the estimates by assessing what would happen if they were relaxed.

(a) Fixed smooth age structure and quasi-stability

The first assumption to be examined is that the underlying smooth structure of the reported age distributions at two successive censuses is unchanged. In applying the method, stable population age distributions selected from the Coale-Demeny Regional Tables (1966) for Turkey, and the Carrier-Hobcraft Tables (1971) for Ghana, Uganda, the Fiji Islands, the Island of Mauritius and Mexico, were taken as approximation to the smooth age structure of the true populations. In practice, alteration in the smooth age structure at two censuses separated by only a five or ten year interval are likely to be small compared with the biases which come from other variations due to, for example, migration effects and coverage and age errors.

This assumption presupposes a quasi-stable situation in which the changing mortality affects the age distribution little for a fixed fertility. The quasi-stability aspect of the method has been tested as follows:-

(i) The fertility pattern is fixed per unit of total fertility in the distribution shown in Table 6.21, taking the observed measures from the Turkish demographic survey of 1966-67 as a base (see Shorter and Pasta, 1974, p.36).

(ii) The expectation of life at birth, e_o^o, for males and females is assumed to be 46.8 and 49.4 years respectively, as estimated by the Demeny and Shorter 'hybrid' method for 1955-60 (see Demeny and Shorter, 1968, p.28).

(iii) The sex ratio at birth is assumed to be 1.05, a typical value for the population.

TABLE 6.21: Distribution per Unit of Total Fertility: Turkey: 1966-67

Age group of women	Distribution of Fertility
15-19	.015
20-24	.051
25-29	.049
30-34	.039
35-39	.028
40-44	.012
45-49	.006
Total Fertility	1.000

Source: Shorter, F.C., and Pasta, D; Computational Methods for Population Projections with Particular reference to Development Planning, Population Council, 1974, Table 2.4.

(iv) The total population, 24,190,000, is as recorded and adjusted for international migration and territorial changes for 1955 by Demeny and Shorter (1968, p.54), with the growth rate, r= 0.025 .

(v) As before, the Turkish population is assumed to follow the mortality pattern of the South model of the Coale-Demeny Regional Tables (1966).

(vi) The information contained in (i) to (v) is fed into the standard computer programme described in the Demographic Computer Library by Shaw and Johnson (1971) of the U.S. Bureau of Census. In the Demographic Computer Library programme populations are projected by using the Coale-Demeny Regional Tables (1966). By trial and error methods the total fertility rate that is appropriate for the stable age structure is fixed at 5.96. This total fertility rate is close to the 5.78 value calculated by Shorter and Pasta (1974, p.37) for 1965-70 from the crude birth rate and midperiod population.

(vii) With a total fertility rate of 5.96 and on the assumption that the e_0^o for both sexes are increasing at the tempo of 0.5 years per annum (2.5 years in 5 years), projections ahead are constructed as in (vi). The percentage age distributions for females five and ten years ahead are compared with the baseline values in Table 6.22.

(viii) These constructed female age distributions are then treated by the application of the period-age interval method and its extension to give estimates of the biases arising from the assumed declining mortality. The estimates are shown in Tables 6.23 and 6.24 for the period-age interval method and its extension respectively. It is encouraging to note that the test shows the effect of declining mortality (annual rate of 0.5 year in e_0^o) due to the period-age interval method to be less than 3% (see column 1 in Table 6.23) and due to the extension of the method to be less than 1.5% (shown in Table 6.24, column 1).

TABLE 6.22: Projected Populations, assuming a fixed fertility and Declining Mortality for the South Model

Age Group	Female % distribution from South model, e_o^o=49.4, r=.025	Projected Population	
		5 years ahead	10 years ahead
0-4	16.41	16.41	16.60
5-9	13.36	13.39	13.42
10-14	11.57	11.59	11.55
15-19	10.04	10.06	10.00
20-24	8.67	8.68	8.64
25-29	7.45	7.46	7.43
30-34	6.39	6.40	6.37
35-39	5.47	5.48	5.46
40-44	4.67	4.67	4.65
45-49	3.96	3.97	3.95
50-54	3.33	3.34	3.33
55-59	2.75	2.76	2.75
60-64	2.20	2.20	2.20
65-69	1.65	1.65	1.65
70-74	1.11	1.11	1.12
75-79	.63	.63	.64
80+	.35	.22	.23
TOTAL	100.00	100.00	100.00

TABLE 6.23: The Effect of Declining Mortality on the Results of the Period-Age Interval Method applied to Turkish female data 1955 and 1960 censuses

Age Group	Effect of declining Mortality	Real fluctuations from Period-Age Interval Method Applied to 1955-60 data	Effect of Mortality decline removed from real fluctuations
	1	2	3 = 1x2
0-4	.9941	.9945	.9886
5-9	.9941	1.0322	1.0261
10-14	.9918	.9602	.9523
15-19	.9901	.8077	.7997
20-24	.9882	.9539	.9426
25-29	.9870	1.0792	1.0652
30-34	.9857	1.0767	1.0613
35-39	.9842	.9178	.9033
40-44	.9824	.7990	.7849
45-49	.9824	1.0383	1.0200
50-54	.9799	1.1286	1.1059
55-59	.9770	1.1761	1.1490
60-64	.9734	1.1285	1.0985
65-69	.9734	1.0886	1.0596
70-74	.9734	1.0123	.9854
75-79	.9734	1.0194	.9923

TABLE 6.24: The Effect of Declining Mortality on the Results of the Extended Method in Section 6.4, applied to Turkish female data, 1950 and 1960 censuses

Age Group	Effect of Mortality Decline	Real Fluctuations from Extended Method Applied to 1950-60 data	Effect of Mortality decline removed from the real fluctuations
	1	2	3 = 1x2
0-4	.9889	1.009	.998
5-9	.9900	.981	.971
10-14	.9906	.955	.946
15-19	.9940	.821	.816
20-24	.9940	.905	.900
25-29	.9966	1.134	1.130
30-34	.9971	1.019	1.016
35-39	.9985	.945	.944
40-44	1.0014	.797	.798
45-49	1.0010	1.067	1.068
50-54	1.0014	1.129	1.131
55-59	1.0010	1.241	1.242
60-64	1.0014	1.194	1.196
65-69	1.0010	1.140	1.141
70-74	.9925	1.215	1.206
75-79	.9854	1.076	1.060

Lastly, the effect that declining mortality (at 0.5 year in e_o^o annually) would have on the estimates of real fluctuations from the 1955 and 1960 (for period-age interval method) and 1950 and 1960 (for the extension) census data for Turkish females is removed by multiplying columns 1 and 2 to obtain column 3 of both Tables 6.23 and 6.24. A comparison of columns 2 and 3 of both tables shows only slight variations in level and pattern, implying that the effect of changing mortality in the application of the method and its extension are likely to be very small.

(b) Cohort fluctuation

The second assumption made by the method and its extension is that real fluctuations are the same for a birth cohort at the two censuses. It presupposes negligible effects due to migration and to mortality change during the intercensal period. There is no doubt that the presence of heavy international migration would substantially distort the results, unless an adjustment could be made. However, the use of percentages rather than population numbers would reduce the bias to the extent that the migration was not age selective. The results of the application of the method to particular countries (mainly Uganda and Mexico) suggest that the distortion would depress the fluctuation estimates at early adult ages relative to the younger and older groups. The pattern over the preceding ten to fifteen years might not be much affected.

(c) Coverage and Age errors

The third assumption of the method to be considered is that the structure of coverage and age errors in the two successive censuses is the same in the corresponding age groups, that is, the proportional error is constant by age. This assumption is critical in countries that have been improving their methods of enumeration, and thus reducing the overall coverage error at later censuses. Clearly the effect of a varying proportional coverage error would be similar to changes in age misstatement, possibly of a large size, and could lead to badly distorted results from the method.

In practice, the coverage errors vary with age groups because they are related to different factors, such as migration and sociocultural aspects, which have a more pronounced effect at some ages than at others. For example, in some populations males in the working age groups tend to be omitted from censuses because of their greater mobility as migrant labour, and children may not be counted, for socio-cultural reasons. Errors introduced into the estimates by varying coverage may be detected by comparison with results of the procedure applied to other pairs of censuses for the same country by tracing cohorts, as has been done in Tables 6.2 to 6.5 for Turkey. However, in countries where there have been no more than two modern censuses and in which there is considerable doubt about the constancy of coverage errors, it might be useful to examine possible changes in such errors to discover how sensitive the results are to the assumptions.

The assumption of constant proportional age error in the corresponding age groups at two consecutive censuses seems realistic so far as the method is applied to quinquennial data, but there are difficulties in using single year and decennial data. Problems arise with the use of ten-year inter-censal data because the interval is too long to assume minimal changes in the proportional age error in the light of rapid changes in social and economic factors. In addition, by use of data from the 1962 and 1972 censuses of the Island of Mauritius, it has already been demonstrated that applying the method to single-year age data which have differences in the patterns of digit preference error as a consequence of changing collection procedures at successive censuses, is likely to lead to misleading results.

6.7. Conclusion

In this chapter, a method for estimating real fluctuations and true age distributions from two consecutive censuses has been presented and discussed. The method and its extensions have been applied to a variety of age data observed in censuses that are five or ten years apart. The results obtained, in age groups of one, five and ten years, show high consistency and seem plausible.

In general, the method and its extensions make three assumptions. The first assumption, that the underlying smooth structure of the age distributions at the two consecutive censuses is fixed, presupposes a quasi-stability situation in which the changing mortality has a small effect on the results for a fixed fertility. The impact of relaxing the assumption on the estimates from the method has been assessed and found small. Secondly, the method assumes that the cohort fluctuations are the same at the two censuses. Although there is a danger of heavy migration distorting the results, the pattern of the estimates may be representative of the true situation for ten to fifteen years preceding the census date. Lastly, the method assumes a constant structure of proportional age and coverage errors in each census. This assumption seems plausible in countries like Turkey, where the intercensal intervals are short and Fiji, whose data from the two censuses do not vary greatly qualitatively.

CHAPTER SEVEN

SUMMARY OF THE MAIN CONCLUSIONS AND RECOMMENDATIONS

The thesis is an attempt to examine methods to detect, measure and adjust for age and coverage errors in censuses of Africa and other developing regions. Different methods of error analysis have been proposed and discussed in such detail that it is impracticable to summarise them fully, here. In this chapter, therefore, we shall summarise the main conclusions of each of the preceding five chapters separately, and make recommendations about future research arising from the study.

7.1. Age Heaping in African censuses

The problem of age heaping in African censuses and surveys was investigated in Chapter two. By the use of the Myers method, a study of twenty-six male and female populations from thirteen censuses was made, in which indices of age heaping were measured. It was found that in most of the populations in the study, ages were heaped on terminal digits 0 and 5, and that even digits were more favoured than odd ones. These results are in conformity with the outcome of previous studies. The exceptions to these findings were traceable to the way in which the census questions on age had been asked.

On the basis of the conclusions, ages were regrouped and the distributions for various populations were adjusted for heaping errors. The adjustment did not, however, eliminate most of the irregularities in age distributions, because factors other than digit preference were responsible for the anomalies.

7.2. Patterns of Age and Coverage Errors in Africa

In Chapter Three an attempt was made to determine whether there were discernible patterns of age and coverage errors in tropical African censuses. Age percent distributions of forty-three African populations, observed at censuses and surveys held between 1950 and 1973, were averaged to provide a standard with which to investigate deviations of individual populations from the overall pattern. By the use of the logit transformation to compare curves for individual populations with the overall average, it was established that patterns of deviations of individual populations from the average could be classified into four groups. A closer examination of censuses and surveys in each group revealed that similar survey methods had been used. Also, the study showed a close agreement between the error pattern of the male population and those for females in the same inquiry.

In addition to revealing differences, the study showed some broad similarities of error patterns, a finding consistent with the idea that there is basic African error regularity with superimposed variations.

7.3. Sex Differential Errors:

Chapter Four contains discussion of the sex differential in age errors in African censuses and surveys. By the use of data in which questions on orphanhood were asked, direct and analytic methods were applied to examine whether males ages were misreported differently from females. The study demonstrated that young females tended to overstate their ages relative to males, while the reverse held in later periods of life.

However, the methods employed in the analysis have shortcomings that arise from some of the assumptions that are needed. Firstly, the assumption made in the direct method that the proportions for both sexes together with surviving parents are accurate, implies that when males reported higher ages, the females reported lower ages than the true values. Such a proposition is unrealistic, since there is nothing to prevent both sexes reporting ages with errors in the same direction. Secondly, the assumption made in both methods, that there is no differential survivorship of parents according to the sexes of their children, cannot be verified by the available data.

Nevertheless, the assumption that the reporting of the proportions of parents alive have the same relative error for both sexes, seems plausible in some surveys. Also, the pattern in the estimates of deviations is consistent. This provides further evidence for the broad validity of the conclusions about the characteristics of the errors.

7.4. The Demeny-Shorter method and the Three-Censuses Analysis

In Chapter Five, a critical examination of the assumptions of the Demeny-Shorter method, in relation to its applicability to African data and to its flexibility, was made. It was found that the technique is sensitive to changes in coverage at successive censuses and that it is not very suitable for the analysis of African data.

A more flexible method is proposed, which uses three successive censuses. This technique relies on two of the three assumptions made in the Demeny-Shorter method, namely that the selected model life table is applicable and the total population is enumerated accurately. However, it has three disadvantages. First, like the Demeny-Shorter method, it depends on selected life table survivorship ratios, which introduces some rigidity in the operation and in the results. Secondly, the technique involves many more computations than the two census Demeny-Shorter method. Thirdly, the applicability of the three-census analysis to data from developing areas is limited to a few countries and cannot be extended to any of the African countries, owing to the lack of the requisite data.

Nevertheless, by the replacement of the third Demeny-Shorter assumption of constant error by a regular reduction of error at successive censuses, the three census technique is likely to be more realistic. This follows from the efforts of census organisers in developing countries to reduce errors by adopting better methods of data collection. In addition, the results from the application of the three-census method to data of some developing countries, including Turkey, the Fiji Islands and Mexico, were consistent, especially at younger ages.

7.5. A New Two-Census Method

A new method for estimating real fluctuations and true age distributions from two successive censuses was presented and discussed in Chapter Six. The technique and its extensions were applied to a variety of age data reported in censuses held five or ten years apart. The results, for data from Africa, Latin America, Euro-Asia and Oceania were consistent and plausible.

In the two-census method three assumptions are made. The first, that the underlying, smooth structure of age distributions at the two consecutive censuses is constant, was tested experimentally by introducing mortality trends while holding fertility constant. The effect of changing mortality was found to be small. Secondly, the assumption that cohort fluctuations are the same at the two censuses seems normally reasonable, particularly for the young ages, although it is sensitive to substantial migration in the census-interval. Finally, the method requires the assumption of a constant structure of proportional age and coverage errors at the two censuses, which is acceptable in countries where the interval is short and the techniques of collection are similar on the two occasions.

7.6. Recommendations for Future Research in Age Errors

In addition to the summary of the main conclusions, it is desirable to make recommendations about some of the areas future research workers in the field of age errors may need to investigate. There was inevitably not enough time in the present study to investigate these topics exhaustively. The first area concerns the size of age errors. Although our study established distinct patterns of age and coverage errors in African censuses and surveys, it paid relatively little attention to the sizes of the errors. Efforts to establish levels of age and coverage errors in previous African demographic inquiries would be worthwhile because this knowledge is important for the field demographers who will be concerned with reducing errors in the future.

A second topic for research is the use of data on spouse and sibling survival. An investigation into the development of methods based on data on the survival of spouse and siblings would help in the analysis of sex differentials of errors. K. Hill (1975) has developed a technique that uses widowhood data for the estimation of mortality. Although the widowhood technique has not yet been widely used, it may be possible to adapt it to throw light on sex differential errors, much as the orphanhood method was in Chapter Four. Hill(1977) has also begun to develop a method that uses data on the survival of siblings (brothers and sisters) to estimate child and adolescent mortality. It could be adapted similarly. These two approaches, widowhood and surviving siblings, would yield errors estimates that could provide a check on the consistency of the findings from the orphanhood method. A difficulty at present is that there have been few censuses or surveys where questions on widowhood of first spouse have been asked, and fewer still which provide data on surviving siblings. However, once these methods have been established, questions on these topics are likely to be included in future demographic inquiries.

A third recommendation for future research arising from our study, is on the modification of the two and three-census analyses in Chapter Five. Since the results at young ages are consistent and plausible, it may be worthwhile to assume approximate equality of true numbers in the first few five year age groups for the two sexes. This would give extra equations which might enable other assumptions to be relaxed. The results from such an exercise could provide a check on the estimates derived from the original forms of the techniques.

APPENDICES

AND

BIBLIOGRAPHY

APPENDIX TABLE 2.1.

Sprague Multipliers

The <u>mid-panel</u> multiplyers are as follows:

	N_1	N_2	N_3	N_4	N_5	Sum
n_1..........	-.0128	+.0848	+.1504	-.0240	+.0016	+.2000
n_2..........	-.0016	+.0144	+.2224	-.0416	+.0064	+.2000
n_3..........	+.0064	-.0336	+.2544	-.0336	+.0064	+.2000
n_4..........	+.0064	-.0416	+.2224	+.0144	-.0016	+.2000
n_5..........	+.0016	-.0240	+.1504	+.0848	-.0128	+.2000

The <u>next-to-the-end-panel</u> multiplyers are as follows:

<u>First next-to-the-end-panel</u>

	N_1	N_2	N_3	N_4	Sum
n_1........	+.0336	+.2272	-.0752	+.0144	+.2000
n_2........	+.0080	+.2320	-.0480	+.0080	+.2000
n_3........	-.0080	+.2160	-.0080	+.0000	+.2000
n_4........	-.0160	+.1840	+.0400	-.0080	+.2000
n_5........	-.0176	+.1408	+.0912	-.0144	+.2000

<u>Last next-to-the-end-panel</u>

	N_1	N_2	N_3	N_4	Sum
n_1........	-.0144	+.0912	+.1408	-.0176	+.2000
n_2........	-.0080	+.0400	+.1840	-.0160	+.2000
n_3........	+.0000	-.0080	+.2160	-.0080	+.2000
n_4........	+.0080	-.0480	+.2320	+.0080	+.2000
n_5........	+.0144	-.0752	+.2272	+.0336	+.2000

APPENDIX TABLE 2.1 (continued)

The end-panel multiplyers are as follows:

First end-panel

	N_1	N_2	N_3	N_4	Sum
n_1.........	+.3616	-.2768	+.1488	-.0336	+.2000
n_2.........	+.2640	-.0960	+.0400	-.0080	+.2000
n_3.........	+.1840	+.0400	-.0320	+.0080	+.2000
n_4.........	-.1200	+.1360	-.0720	+.0160	+.2000
n_5.........	+.0704	+.1968	-.0848	+.0176	+.2000

Last end-panel

	N_1	N_2	N_3	N_4	Sum
n_1.........	+.0176	-.0848	+.1968	+.0704	+.2000
n_2.........	+.0160	-.0720	+.1360	+.1200	+.2000
n_3.........	+.0080	-.0320	+.0400	+.1840	+.2000
n_4.........	-.0080	+.0400	-.0960	+.2640	+.2000
n_5.........	-.0336	+.1488	-.2768	+.3616	+.2000

SOURCE: *Reprinted from: A. J. Jaffe. 1951. Handbook of Statistical Methods for Demographers; Selected Problems in the Analysis of Census Data. Washington: Government Printing Office, pp. 95-96.*

APPENDIX TABLE 3.1: REPORTED PERCENT AGE DISTRIBUTIONS OF 50 AFRICAN MALE AND FEMALE POPULATIONS BETWEEN 1950 AND 1973

COUNTRY AND YEAR OF CENSUS OR SURVEY		AGE GROUPS 0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65+	TOTAL
OVERALL AVERAGE	M	17.31	15.38	11.22	8.39	7.38	7.70	6.48	6.12	4.87	4.31	3.22	2.34	1.88	3.40	100.00
	F	17.01	14.36	9.72	8.59	9.00	8.92	7.27	6.22	4.82	3.88	2.99	2.08	1.84	3.30	100.00
ANGOLA 1950	M	15.19	14.39	11.44	8.71	9.44	9.00	6.86	6.70	5.08	4.19	2.62	1.87	1.63	2.88	100.00
	F	15.19	12.77	9.48	8.15	9.82	9.56	8.15	7.14	5.65	4.26	2.99	1.91	2.13	2.81	100.01
ANGOLA 1960	M	16.66	14.98	10.57	8.41	8.50	8.78	7.14	6.55	5.05	4.04	2.76	1.99	1.80	2.77	100.00
	F	17.68	14.46	9.00	7.26	8.82	9.51	8.16	6.80	5.29	3.96	2.86	1.85	1.95	2.39	99.99
BOTSWANA 1964	M	15.06	16.96	12.89	9.86	7.07	6.92	5.22	5.62	3.99	4.31	3.24	2.64	2.24	3.97	99.99
	F	14.76	16.22	11.75	9.51	8.11	7.65	5.83	5.84	4.23	3.89	3.00	2.40	2.06	4.75	100.00
BOTSWANA 1971	M	17.73	16.61	13.65	9.91	6.79	5.79	4.93	4.37	3.86	3.80	3.05	2.43	1.96	5.10	100.00
	F	16.33	15.02	12.58	10.26	8.20	6.57	5.36	4.93	3.99	3.91	2.80	2.40	2.00	5.66	100.01
BURUNDI 1965	M	19.93	17.67	9.88	8.48	8.05	7.16	5.49	5.70	2.93	4.05	2.49	2.92	1.36	3.90	100.01
	F	19.48	16.58	10.15	7.62	7.45	7.16	5.74	5.39	3.25	4.26	3.28	3.18	1.91	4.56	100.01
WEST CAMEROONS 1964-65	M	19.46	16.99	11.77	7.92	7.05	8.55	6.42	6.54	3.96	4.28	2.56	2.18	1.05	1.30	100.01
	F	19.97	16.44	9.17	8.91	10.23	9.69	7.42	5.53	4.06	3.43	2.15	1.49	.75	.77	100.01
CHAD 1963-65	M	20.46	19.60	10.08	6.26	5.00	6.84	6.51	6.85	4.94	4.70	2.96	2.02	1.84	1.93	99.99
	F	18.39	16.31	6.81	7.68	8.71	10.10	[illegible]	7.48	4.80	4.08	2.71	1.86	1.49	1.89	99.99
CONGO 1960-61	M	17.00	15.57	13.62	5.25	5.55	4.95	6.00	4.99	7.80	5.22	5.44	3.38	3.49	1.73	99.99
	F	15.01	13.03	9.44	4.93	7.14	6.43	9.06	7.04	9.57	5.38	5.57	2.72	3.01	1.67	100.00
CENTRAL AFRICAN REPUBLIC 1959-60	M	17.18	16.73	9.11	5.06	5.22	8.45	7.43	10.00	6.52	6.64	2.99	2.35	1.16	1.16	100.00
	F	16.24	14.66	6.36	4.83	8.10	11.91	10.17	10.83	6.19	5.34	1.92	1.72	.89	.83	99.99
CENTRAL AFRICAN REPUBLIC 1966	M	16.85	13.54	11.69	10.23	9.08	8.00	7.00	6.03	5.03	4.02	3.09	2.42	1.50	1.52	100.00
	F	16.39	13.28	11.43	9.95	8.64	7.46	6.42	5.49	4.74	4.09	3.48	2.71	2.26	3.65	99.99
DAHOMEY 1961	M	20.13	17.82	10.49	6.76	5.88	6.97	5.51	6.13	4.24	4.20	3.00	2.62	1.98	4.27	100.00
	F	19.45	15.80	8.41	7.07	9.27	9.20	6.92	5.92	4.23	3.76	2.68	2.34	1.70	3.26	100.01
ETHIOPIA 1965	M	17.68	17.11	11.13	8.44	6.15	7.15	6.89	6.11	4.98	3.46	3.49	2.28	5.21	0.00	100.00
	F	17.38	16.25	9.13	7.73	8.73	9.60	8.53	5.82	5.57	2.74	3.37	1.23	3.92	0.00	100.00
GABON 1961	M	12.91	11.32	9.02	5.11	6.72	7.58	6.91	8.51	7.88	8.22	5.15	3.91	2.84	3.94	100.02
	F	11.39	9.15	6.09	5.32	7.34	8.62	8.92	10.59	8.37	7.16	4.98	3.90	3.07	5.09	99.99
GAMBIA 1973	M	16.52	14.76	9.85	7.78	8.34	8.89	7.29	5.63	4.95	3.67	3.58	2.11	2.39	4.22	99.98
	F	17.24	15.04	9.44	8.82	9.26	10.13	7.52	5.26	4.72	2.82	3.06	1.31	1.94	3.44	100.00
GHANA 1960	M	18.89	15.16	10.52	8.10	7.89	8.19	7.13	5.83	4.88	3.61	2.85	1.74	1.87	3.32	99.98
	F	19.67	15.12	9.72	7.98	9.70	9.21	7.39	5.39	4.38	2.87	2.46	1.46	1.64	3.02	100.01
GHANA 1970	M	18.32	17.14	12.11	9.39	7.19	6.83	6.21	5.21	4.11	3.39	2.82	1.80	1.77	3.71	100.00
	F	18.21	16.74	11.32	8.79	8.71	7.92	6.88	5.03	4.07	2.97	2.59	1.53	1.65	3.57	99.98
GUINEA 1955	M	19.04	17.23	9.41	8.27	6.12	7.01	5.23	6.36	4.83	4.76	3.15	3.08	1.80	3.72	100.01
	F	17.52	14.54	6.82	9.50	9.21	9.94	6.75	7.30	4.68	4.44	2.59	2.30	1.45	2.96	100.00
GUINEA BISSAU 1950	M	12.99	15.00	10.98	8.04	7.30	8.34	6.99	6.72	6.40	5.14	4.04	2.40	2.39	3.27	100.00
	F	13.20	12.96	8.01	6.83	9.32	11.62	9.41	7.92	6.88	4.27	3.12	1.64	1.94	2.90	100.02
IVORY COAST (1ST.SURVEY) 1957-58	M	14.26	10.66	6.49	6.27	10.12	13.66	11.82	9.58	6.47	4.36	2.38	1.81	.87	1.25	100.00
	F	16.91	12.03	5.04	9.04	16.20	14.15	9.18	6.60	3.45	2.44	1.35	1.33	.67	.99	99.98

APPENDIX TABLE 3.1 (continued)

IVORY COAST (2ND.SURVEY) 1957-58	M	17.30	13.66	11.96	10.38	8.80	7.47	6.44	5.59	4.86	4.07	3.28	2.49	1.82	1.88	100.00
	F	17.24	13.61	11.98	10.34	8.77	7.50	6.41	5.57	4.84	4.11	3.33	2.54	1.82	1.94	100.00
KENYA 1962	M	17.79	16.01	13.92	9.86	6.74	6.89	5.62	5.02	4.12	3.70	2.81	1.88	1.91	3.73	100.00
	F	17.84	15.46	11.69	9.49	9.41	8.94	6.75	5.16	4.05	3.07	2.43	1.40	1.59	2.72	100.00
KENYA 1969	M	19.30	16.72	13.63	10.22	7.81	6.38	5.12	4.60	3.54	3.15	2.42	2.09	1.87	3.76	100.01
	F	19.16	16.36	12.10	9.98	8.24	7.53	5.48	4.65	3.70	3.00	2.55	1.67	1.73	3.39	100.00
LESOTHO 1966	M	16.52	17.29	16.70	10.88	4.50	3.90	4.15	3.84	3.57	4.72	3.67	2.83	2.23	5.20	100.00
	F	12.80	13.02	12.63	10.09	7.74	6.52	6.48	4.93	4.23	4.86	4.03	2.80	2.51	7.37	100.01
LIBERIA 1962	M	16.21	13.66	8.64	7.79	6.98	7.99	7.30	6.84	6.23	4.91	3.92	2.64	2.61	4.36	100.00
	F	16.33	12.66	6.85	8.59	9.67	10.74	8.82	6.82	5.31	3.81	2.84	1.85	2.10	3.61	100.00
LIBERIA 1971-72	M	17.40	15.16	11.36	8.44	6.18	7.43	6.50	6.55	5.12	4.29	3.44	2.32	2.03	3.78	100.00
	F	16.13	14.18	9.98	6.81	9.36	10.78	7.84	6.70	4.61	3.31	2.80	1.59	1.73	3.09	100.01
MADAGASCAR 1966	M	18.54	15.88	14.05	8.83	6.33	5.35	5.12	5.05	4.36	4.10	3.48	2.76	1.97	4.17	99.99
	F	17.85	14.48	12.29	9.56	7.21	7.30	5.69	5.72	4.48	4.03	3.11	2.83	1.72	3.74	100.01
MALAWI 1966	M	19.14	15.45	11.37	10.02	7.11	6.68	5.27	5.57	3.64	4.36	2.89	2.49	1.74	4.28	100.01
	F	17.97	14.20	9.94	9.87	8.39	6.20	6.20	6.28	4.01	4.61	2.72	2.31	1.56	3.74	100.00
MALAWI 1971-72	M	17.28	15.80	13.42	9.94	6.81	5.60	5.06	4.89	4.82	3.50	3.74	2.63	6.49*	0.00	99.98
	F	15.86	14.29	11.96	9.96	9.26	6.75	6.22	5.43	5.21	3.41	3.85	2.23	5.56*	0.00	99.99
MALI 1960-61	M	18.96	15.33	9.63	7.50	7.21	7.82	6.41	6.23	5.21	4.62	3.20	2.81	2.03	3.04	100.00
	F	18.05	14.08	8.53	7.74	8.55	8.73	7.14	6.75	5.37	4.37	3.17	2.58	1.98	2.96	100.00
MAURITANIA 1964-65	M	17.82	14.39	12.12	9.20	7.98	7.26	6.17	5.52	4.85	4.04	3.30	2.45	1.88	3.01	99.99
	F	17.41	14.04	12.09	9.19	8.06	7.29	5.99	5.45	4.57	4.00	3.37	2.87	2.31	3.35	99.99
MOZAMBIQUE 1950	M	16.18	15.16	12.67	7.35	7.69	8.07	7.25	7.32	5.84	4.68	2.33	1.46	1.70	2.30	100.00
	F	15.27	12.77	9.12	6.40	8.15	9.08	9.05	7.93	6.46	4.66	2.98	2.11	2.88	3.12	99.98
MOZAMBIQUE 1960	M	17.02	15.94	11.68	6.86	7.80	8.36	6.94	6.60	5.10	4.62	2.99	2.10	1.42	2.56	99.99
	F	16.63	13.91	9.08	5.91	8.57	9.61	7.82	7.33	5.81	4.70	3.18	2.35	1.74	3.36	100.00
NAMIBIA 1951	M	9.90	8.09	7.53	8.94	13.71	13.69	8.82	6.49	5.47	3.87	3.45	2.62	2.69	4.72	99.99
	F	13.34	10.91	9.99	7.86	8.29	8.12	7.66	7.06	5.81	4.10	3.95	3.08	3.26	6.57	100.00
NAMIBIA 1960	M	15.63	13.17	10.60	8.33	7.62	8.51	7.59	6.96	5.39	4.35	2.94	2.28	1.89	4.75	100.01
	F	16.26	13.10	10.51	8.51	6.47	8.06	7.35	5.93	4.94	3.86	2.99	2.32	2.20	5.51	100.01
NIGER 1959-60	M	19.58	17.03	10.36	8.30	6.48	8.58	5.58	6.34	3.56	4.41	2.58	2.40	1.54	3.25	99.99
	F	17.93	14.66	8.07	10.68	9.78	11.72	5.28	6.45	3.04	3.82	1.97	2.10	1.28	3.22	100.00
NIGERIA 1963	M	16.75	15.51	11.58	8.90	11.22	9.27	7.51	4.77	4.66	2.43	2.43	.99	1.59	2.40	100.01
	F	17.56	14.80	9.73	9.98	13.68	10.76	8.04	4.13	4.00	1.76	1.94	.68	1.23	1.73	100.02
RHODESIA 1969	M	16.34	17.45	13.65	10.20	7.39	6.75	6.21	5.56	4.21	4.04	2.89	2.09	.99	2.22	99.99
	F	17.36	17.56	13.70	10.24	8.94	7.52	6.19	5.26	3.62	3.42	2.08	1.44	.78	1.88	99.99
RWANDA 1970	M	17.17	13.88	13.44	10.65	7.28	5.98	5.36	5.13	4.50	4.21	3.86	3.42	5.13*	0.00	100.01
	F	16.32	13.69	13.21	10.92	7.32	6.25	5.54	5.15	4.69	4.34	3.92	3.46	5.19*	-0.00	100.00
SENEGAL 1960-61	M	18.74	16.26	9.04	6.81	6.86	7.96	6.86	5.97	4.63	4.69	3.43	2.85	2.07	3.83	100.00
	F	18.62	14.86	7.46	8.29	9.02	10.41	7.13	6.12	4.22	3.89	2.73	2.00	1.65	3.59	99.99
SIERRA-LEONE 1963	M	17.33	13.47	7.03	7.66	6.99	8.65	7.56	6.70	5.83	4.62	3.67	2.24	2.79	5.47	100.01
	F	17.29	12.29	6.04	10.14	10.48	10.39	8.22	5.82	4.71	3.24	2.75	1.60	2.35	4.67	99.99
SOUTH AFRICAN BANTU 1951	M	13.78	12.68	11.84	10.29	8.85	8.68	7.78	6.55	5.31	4.24	3.42	1.81	1.63	3.16	100.02
	F	14.94	13.06	11.89	10.12	8.93	7.71	7.46	5.64	4.97	3.79	3.50	1.87	2.17	3.96	100.01

APPENDIX TABLE 3.1 (continued)

SPANISH SAHARA 1967	M	15.68	14.40	11.56	8.28	8.85	8.93	7.08	6.07	5.36	3.63	3.13	1.67	1.99	3.35	99.98
	F	16.48	14.32	11.24	10.02	10.29	8.54	7.44	5.50	4.63	2.78	2.82	1.27	2.12	2.55	100.00
SWAZILAND 1966	M	17.55	17.02	14.08	10.14	6.09	6.99	4.88	5.94	3.48	3.57	3.22	1.97	1.72	3.35	100.00
	F	16.88	15.81	12.60	9.75	8.12	8.09	5.35	5.13	3.55	3.34	2.80	1.75	1.72	4.90	99.99
TANGANYIKA 1967	M	18.15	16.22	11.02	8.59	6.32	7.67	5.93	5.67	3.64	4.22	2.92	1.81	1.78	6.08	100.02
	F	17.71	15.34	9.48	9.14	8.64	9.11	6.35	5.34	3.71	3.71	2.88	1.64	1.63	5.12	100.00
TOGO 1958-60	M	22.46	19.74	8.58	6.19	6.00	7.26	5.25	5.65	4.01	4.01	2.69	1.96	1.69	4.50	99.99
	F	20.70	16.24	6.52	6.02	9.46	10.64	6.49	6.09	4.14	3.96	2.54	1.90	1.59	3.73	100.02
UGANDA 1959	M	17.33	13.68	10.62	8.71	8.00	7.97	7.16	6.30	5.47	4.60	3.52	2.47	1.85	2.32	100.00
	F	17.38	13.30	10.50	9.16	9.12	8.75	7.54	6.35	5.23	4.05	2.93	2.18	1.62	1.90	100.01
UGANDA 1969	M	18.96	15.33	11.91	8.62	7.02	7.31	6.33	5.38	4.12	3.52	3.10	2.03	2.06	4.30	99.99
	F	19.74	15.54	11.04	8.77	8.08	8.06	6.34	5.04	4.07	3.17	3.07	1.73	1.94	3.39	99.98
UPPER VOLTA 1960-61	M	18.33	16.14	9.96	8.17	6.97	7.77	5.78	6.38	4.58	4.58	2.99	2.59	1.99	3.78	100.01
	F	17.07	14.26	7.43	7.43	9.64	9.64	7.43	7.43	4.82	4.52	2.81	2.61	2.01	2.81	100.01
ZAIRE 1955-57	M	17.00	13.00	11.02	6.52	7.07	8.53	8.07	7.06	5.65	5.59	4.47	1.92	1.50	2.61	100.01
	F	16.78	12.79	8.22	7.19	8.28	9.21	10.58	7.58	6.02	4.48	3.67	1.61	1.41	2.18	100.00
ZAMBIA 1969	M	19.11	16.28	12.12	8.82	6.75	6.31	5.82	5.90	4.39	4.30	3.00	3.21	1.46	2.51	100.00
	F	18.94	15.78	10.85	9.00	9.26	7.82	6.92	5.77	4.17	3.71	2.62	1.98	1.25	1.94	100.01

+ 60+

APPENDIX: TABLE 3.2: Modified Age Percent Distributions of Each Group of Surveys by Sex

Age Group	Pattern 1		Pattern 2		Pattern 3		Pattern 4	
	M	F	M	F	M	F	M	F
0-4	16.95	19.14	17.75	20.07	13.18	14.31	16.72	16.87
5-9	16.52	15.37	16.24	14.75	16.64	16.10	14.64	14.83
10-14	11.09	8.49	10.72	8.22	15.20	13.47	11.93	11.43
15-19	8.14	7.30	7.81	7.42	11.57	10.90	9.78	9.47
20-24	7.72	8.93	7.24	8.44	7.65	8.95	8.80	9.35
25-29	8.20	9.49	7.78	8.58	7.05	7.93	8.64	8.45
30-34	6.73	7.35	6.56	7.15	5.63	6.05	6.59	6.80
35-39	6.04	6.23	6.58	6.85	5.40	5.23	5.57	5.67
40-44	5.18	4.74	5.23	4.99	4.00	3.88	4.21	4.27
45-49	4.11	3.64	4.76	4.18	3.95	3.52	3.55	3.24
50-54	2.82	2.63	3.09	2.85	2.97	2.68	2.67	2.66
55-59	2.06	1.76	2.31	2.25	2.16	1.89	1.94	1.86
60-64	1.62	1.77	1.70	1.73	1.70	1.62	1.71	1.74
65+	2.82	3.16	2.23	2.52	2.90	3.47	3.25	3.36
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

APPENDIX: TABLE 3.3(a): Logit deviations for the additional surveys of Group 1

Under Age	GUINEA BISSAU 1950 M	GUINEA BISSAU 1950 F	IVORY COAST 1st.Survey 1957/8 M	IVORY COAST 1st.Survey 1957/8 F	SPANISH SAHARA 1967 M	SPANISH SAHARA 1967 F
5	.041	-.124	-.341	-.327	-.002	-.020
10	-.054	-.108	-.168	-.134	-.030	-.019
15	-.046	-.008	.016	.108	-.023	.009
20	-.003	.082	.156	.195	.021	.027
25	.033	.101	.194	.123	.027	.009
30	.029	.056	.143	.036	.006	-.005
35	.036	.030	.093	-.010	-.001	-.029
40	.029	.003	.031	-.066	-.010	-.034
45	.002	-.045	-.012	-.050	-.032	-.048
50	-.021	-.044	-.051	-.028	-.019	-.006
55	-.044	-.026	-.026	.065	-.014	-.000
60	-.002	.082	-.034	.089	.076	.118
65	-.018	.125	.063	.206	.109	.093

Under Age	ZAIRE M	ZAIRE F	ZAMBIA M	ZAMBIA F	Total Logit Deviations $D_T(x)$ M	Total Logit Deviations $D_T(x)$ F
5	-.098	-.185	.031	-.049	.007	-.067
10	-.068	-.116	-.026	-.051	-.056	-.080
15	-.044	-.010	-.035	-.006	-.033	-.001
20	.039	.076	-.017	.034	.013	.061
25	.086	.116	.015	.036	.039	.064
30	.085	.118	.033	.035	.030	.027
35	.071	.060	.041	.024	.027	.008
40	.054	.032	.023	.006	.014	-.017
45	.046	.004	.027	.010	-.007	-.028
50	-.009	-.017	-.000	-.010	.028	-.028
55	-.100	-.074	.001	-.013	-.018	-.003
60	-.062	-.005	-.092	-.018	.013	.068
65	-.013	.046	-.075	.016	.051	.110

APPENDIX:TABLE 3.3(b): **Logit deviations for the additional surveys of Group 2**

Up to Age	WEST CAMEROONS 1964/5 M	F	CENTRAL AFRICAN REPUB. 1959/60 M	F	CONGO 1960/61 M	F	IVORY COAST 2nd. Survey 1957/58 M	F	TOTAL LOGIT DEVIATIONS $D_T(x)$ M	F
5	-.061	-.168	-.145	-.306	.056	-.102	-.021	-.019	-.021	-.097
10	-.075	-.111	-.167	-.221	-.035	-.106	-.006	-.005	-.068	-.086
15	-.039	.013	-.073	-.028	-.098	-.061	-.002	-.002	-.036	-.002
20	.028	.089	.057	.142	-.021	.048	.003	.002	.017	.058
25	.079	.100	.156	.217	.027	.089	.009	.009	.053	.071
30	.067	.076	.172	.195	.072	.131	.016	.015	.054	.056
35	.074	.059	.190	.176	.084	.108	.022	.021	.060	.046
40	.035	.047	.111	.074	.108	.111	.023	.023	.037	.011
45	.049	.041	.076	.034	.038	.014	.017	.019	.021	-.003
50	-.011	-.006	-.068	-.100	.010	-.005	.005	.006	-.027	-.026
55	-.029	-.038	-.104	-.066	-.088	-.110	-.017	-.017	-.040	-.018
60	-.118	-.103	-.206	-.119	-.152	-.118	-.049	-.051	-.051	-.010
65	-.121	-.119	-.254	-.132	-.483	-.374	-.118	-.114	-.069	-.006

APPENDIX: TABLE 3.3(c): Logit deviations for the additional surveys of Group 3

Under Age	CENTRAL AFRICAN REPUB. 1966		SOUTH AFRICAN BANTU 1951		TOTAL LOGIT DEVIATIONS $D_T(x)$	
	M	F	M	F	M	F
5	-.060	.026	-.017	.024	.155	.107
10	-.025	.007	-.011	.007	.028	.014
15	-.001	-.003	-.009	-.008	-.042	-.019
20	.018	-.007	.003	-.008	-.065	-.029
25	.031	-.011	.019	-.008	-.042	-.031
30	.037	-.012	.016	-.007	-.034	-.043
35	.037	-.012	.005	-.025	-.016	-.039
40	.031	-.008	-.005	-.021	-.017	-.039
45	.019	-.004	-.012	-.023	.004	-.018
50	.003	.000	-.015	-.005	-.004	-.008
55	-.018	.004	-.025	-.005	.002	.019
60	-.072	.020	.053	.080	.031	.084
65	-.127	.069	.127	.118	.067	.159

APPENDIX: TABLE 3.3(d): The logit deviations (reported-estimated) for additional surveys of Group 4

Survey	GAMBIA 1973		GHANA 1970		LIBERIA 1962		LIBERIA 1971	
Up to Age	M	F	M	F	M	F	M	F
5	.009	-.030	.073	.034	-.025	-.117	.022	-.069
10	-.043	-.050	-.016	-.030	-.062	-.081	-.034	-.064
15	-.015	.008	-.028	-.015	-.017	.033	-.037	.010
20	.023	.042	-.023	.011	.016	.072	-.013	.054
25	.028	.041	-.004	.008	.047	.069	.032	.061
30	-.002	-.010	-.003	-.008	.041	.023	.031	.009
35	-.021	-.038	-.012	-.033	.032	-.012	.030	-.011
40	-.021	-.035	-.021	-.036	.016	-.033	.005	-.042
45	-.024	-.047	-.019	-.035	-.010	-.044	-.007	-.041
50	-.002	-.002	-.011	-.010	-.023	-.028	-.017	-.016
55	-.001	.001	-.001	.012	-.028	.012	-.023	.006
60	.068	.121	.064	.102	.013	.105	.012	.104
65	.087	.166	.113	.170	.017	.151	.040	.164

Survey	NIGER 1959/60		NIGERIA 1963		SIERRA-LEONE 1963		TOTAL LOGIT DEVIATIONS $D_T(x)$	
Up to Age	M	F	M	F	M	F	M	F
5	.017	-.048	-.030	-.121	-.044	-.088	.015	.010
10	-.052	-.043	-.035	-.055	-.073	-.053	-.008	-.016
15	-.024	.050	.001	.050	.002	.065	-.007	-.003
20	.005	.050	.052	.103	.031	.062	.006	.015
25	.043	.041	.021	.041	.055	.033	.009	.007
30	.010	-.050	-.009	-.017	.030	-.019	-.015	-.012
35	.022	-.019	-.041	-.076	.012	-.055	-.021	-.024
40	-.015	-.065	-.030	-.053	-.007	-.059	-.029	-.036
45	.014	-.013	-.060	-.083	-.024	-.056	-.021	-.032
50	-.024	-.027	-.012	-.005	-.027	-.016	-.013	-.011
55	-.000	.043	.001	.020	-.015	.033	.014	.018
60	.003	.082	.141	.197	.062	.153	.071	.086
65	.057	.192	.180	.255	.086	.208	.125	.143

APPENDIX: TABLE 3.4: Logit deviations of the Unclassified Populations

Up to Age	BURUNDI 1965 M	F	MADAGASCAR 1966 M	F	MALAWI 1971/72 M	F	MAURITANIA 1964/65 M	F
5	.056	.063	.112	.042	.125	.050	.016	.037
10	-.039	-.032	.023	.004	.026	.005	-.007	.005
15	-.012	-.024	-.050	-.020	-.035	-.009	-.019	-.017
20	.005	.000	-.051	-.020	-.056	-.011	-.005	-.010
25	.001	.003	-.029	-.000	-.041	-.025	.006	-.006
30	-.011	-.010	-.005	-.005	-.020	-.011	.008	-.009
35	-.006	-.011	.009	.006	-.003	-.006	.012	-.003
40	-.034	-.023	.008	-.004	.003	-.001	.010	-.004
45	.012	.017	.010	-.000	-.008	-.017	.003	.000
50	-.006	.006	-.001	-.005	.010	.012	-.004	.003
55	.031	.015	-.012	.006	-.008	-.015	-.013	.005
60	.003	-.004	-.014	-.003	.007	.027	-.007	-.000
65	.091	.043	.014	.050	--	--	.001	-.023

Up to Age	RHODESIA 1969 M	F	RWANDA 1970 M	F	TANGANYIKA 1967 M	F
5	.058	.016	.073	.072	.081	.031
10	-.021	-.024	.035	.033	-.018	-.028
15	-.039	-.022	-.021	-.018	-.028	.008
20	-.028	.002	-.046	-.047	-.023	.016
25	.005	.012	-.031	-.029	.005	.009
30	.025	.015	-.010	-.011	-.017	-.035
35	.029	.013	.008	.006	-.021	-.044
40	.021	-.002	.016	.017	-.038	-.050
45	.027	.009	.024	.024	-.011	-.022
50	-.005	-.025	.020	.019	-.023	-.013
55	-.026	-.015	-.003	-.003	.003	.014
60	-.047	.019	-.066	-.064	.089	.114
65	.047	.145	--	--	.185	.204

APPENDIX TABLE 4.1: Brass Multiplying Factors

Factors for the Conversion of the Proportions of Children with Surviving Mothers into Life Table Survival Probabilities

(i) B = 22.5 years | (ii) B = 25.0 years

Age Groups of Children	(i) $\bar{M}$ (years)				(ii) $\bar{M}$ (years)					
	22	23	24	25	23	24	25	26	27	28
5-9	0.997	0.999	1.001	1.002	0.997	0.999	1.001	1.002	1.004	1.005
10-14	1.000	1.003	1.006	1.009	0.998	1.001	1.004	1.007	1.010	1.014
15-19	1.003	1.008	1.013	1.018	0.999	1.004	1.009	1.015	1.021	1.027
20-24	1.006	1.014	1.023	1.031	0.998	1.006	1.015	1.024	1.034	1.046
25-29	1.011	1.023	1.037	1.051	0.995	1.008	1.02[illegible]	1.037	1.053	1.072
30-34	1.014	1.033	1.054	1.077	0.987	1.008	1.029	1.053	1.079	1.109
35-39	1.016	1.046	1.078	1.113	0.971	1.001	1.033	1.069	1.109	1.154
40-44	1.006	1.049	1.096	1.148	0.934	0.976	1.023	1.075	1.134	1.200
45-49	0.981	1.040	1.107	1.183	0.868	0.924	0.988	1.060	1.143	1.238
50-54	0.896	0.971	1.059	1.161	0.721	0.786	0.862	0.952	1.057	1.180

(iii) B = 27.5 years | (iv) B = 30.0 years

Age Groups of Children	(iii) $\bar{M}$ (years)						(iv) $\bar{M}$ (years)			
	25	26	27	28	29	30	27	28	29	30
5-9	0.999	1.001	1.002	1.004	1.006	1.008	0.998	1.000	1.002	1.004
10-14	0.999	1.002	1.006	1.009	1.013	1.017	0.998	1.001	1.005	1.010
15-19	0.998	1.004	1.009	1.016	1.023	1.031	0.994	1.001	1.008	1.016
20-24	0.994	1.004	1.014	1.025	1.037	1.051	0.986	0.997	1.009	1.023
25-29	0.986	1.001	1.017	1.035	1.055	1.077	0.973	0.990	1.010	1.031
30-34	0.973	0.995	1.020	1.048	1.079	1.114	0.949	0.975	1.003	1.036
35-39	0.941	0.974	1.011	1.051	1.098	1.150	0.901	0.938	0.979	1.026
40-44	0.890	0.935	0.986	1.044	1.111	1.187	0.824	0.872	0.928	0.992
45-49	0.779	0.836	0.902	0.977	1.065	1.168	0.670	0.726	0.792	0.869
50-54	0.615	0.679	0.754	0.846	0.946	1.069	0.497	0.555	0.624	0.705

$\bar{M}$ - mean age of mothers at birth of children
B - lower limit of the age range over which probability of survival is estimated

Source: Brass, W. (1975) p.68, Table 16.

Computer Program No.1 used to calculate Myers Index in Chapter 2

```
PROGRAM MYERS       74/74    OPT=1                   FTN 4.0+P357      22/05/75  16.31.1C.      PAGE    1

          PROGRAM MYERS(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
          REAL TERDIG(10,6),PROD(2,10),BLEND(10),DEV(10),TITLE(5)
          WRITE(6,88)
     88   FORMAT(1H1,'  ***  START OF JOBS  ***  ')
          DO 99 K = 1,2
          READ(5,111) TITLE
    111   FORMAT(5A10)
          DO 12 M = 1,10
          READ(5,101)(TERDIG(M,L),L=1,6)
    101   FORMAT(6F10.0)
     12   CONTINUE
          N = 1
          IT = 0
          DO 13 MA = 1,2
          DO 14 M = 1,10
          SUM= 0.0
          DO 15 L=N,6
          INDEX = IABS(IT-M)
          SUM = SUM+TERDIG(M,L)*INDEX
     15   CONTINUE
          PROD(MA,M) = SUM
     14   CONTINUE
          IT = 10
          N = 2
     13   CONTINUE
          TOT = 0.0
          DO 16 M = 1,10
          BLEND(M) = PROD(1,M)+PROD(2,M)
          TOT = TOT+BLEND(M)
     16   CONTINUE
          DO 17 M = 1,10
          DEV(M) = (BLEND(M)/TOT)*100-10
     17   CONTINUE
          WRITE(6,1)
      1   FORMAT(/// 7X,'    L1          L2          L3          L4          L5
         +   L6           PROD1        PROD2        BLEND        DEV')
          DO 18 M = 1,10
          WRITE(6,2)M,(TERDIG(M,L),L=1,6),PROD(1,M),PROD(2,M),BLEND(M),
         +DEV(M)
      2   FORMAT(/5X,I2,2X,6(F8.0,2X),1X,F10.0,3X,F10.0,2X,F10.0,3X,F6.2)
     18   CONTINUE
          WRITE(6,3)TITLE
      3   FORMAT(/10X,5A10)
     99   CONTINUE
          STOP
          END
```

Computer Program No.2 using Sprague Multipliers to breakdown five to single year age groups in Chapter 2.

```
PROGRAM SPRGU      74/74    OPT=2                    FTN 4.2+ REL        05/12/76  17.07.09.       PAGE    1

      PROGRAM SPRGU (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      DIMENSION AN(16),S(5,5),P(5),TITLE(8),JJ(16),IFORM(8),JFORM(8)
      WRITE(6,12)
   12 FORMAT(1H1,'  ***  START OF JOBS  ***  ')
      READ  (5,1018)  IFORM,JFORM
      READ  (5,1003) NAN,NSR,NSC
C     NAN REPRESENTS THE NUMER OF N'S FED IN AND NSR NO. OF ROWS NSC NO. COLUMNS
C     OF THE SPRANGUE MULTIPLIERS.
      DO 30 I = 1,NSR
      READ(5,1010)(S(I,J),J=1,NSC)
      WRITE(6,1013)(S(I,J),J=1,NSC)
   30 CONTINUE
      DO 40 I=1,16
   40 JJ(I)=I
      DO 236 LX = 1,8
      READ  (5,1000) TITLE,(AN(I),I=1,NAN)
C     WITH PRESENT FORMAT TITLE CAN NOT EXCEED 80 CHARACTERS.
      WRITE  (6,1005) TITLE,(JJ(I),I=1,NAN)
      WRITE  (6,1007)  (AN(I),I=1,NAN)
      WRITE  (6,1009)
      INCR = 0
   50 IS = INCR+1
      IL = INCR+NSC
      WRITE  (6,1015)  (AN(I),I=IS,IL)
      WRITE  (6,IFORM)
      TOTAL = 0.0
      DO 200 I=1,NSR
      K = INCR
      SUM =0.0
      DO 100 J=1,NSC
      K = K+1
      P(J) = S(I,J)*AN(K)
      SUM=SUM+P(J)
  100 CONTINUE
      WRITE  (6,1020)  (P(L),L=1,NSC),SUM
      TOTAL =TOTAL+SUM
  200 CONTINUE
      WRITE  (6,JFORM) TOTAL
      INCR = INCR+1
      NREM = NAN-INCR
      IF  (NREM.GE.5) GO TO 50
 1000 FORMAT (8A10/8F10.0/8F10.0)
 1003 FORMAT   (3I5)
 1005 FORMAT(5X,8A10/11X,16('N'I2,5X))
 1007 FORMAT(5X,16F7.0)
 1009 FORMAT   (5X,'SPRANGUE MULTIPLIERS'/5X,'--------------------')
 1010 FORMAT   (5F10.4)
 1013 FORMAT   (5X,5F10.4)
 1015 FORMAT   (5X,'PRODUCTS FOR FOLLOWING N S'//5X,5(F10.0,3X))
 1018 FORMAT   (8A10/8A10)
 1020 FORMAT   (5X,5F13.4,6X,F20.4)
  236 CONTINUE
      STOP
      END
```

Computer Program No.3 used to calculate logit deviations and average absolute deviations, in Chapter 3

```
PROGRAM HMMOD         74/74    OPT=2                              FTN 4.2+ REL        10/08/76  11.19.20.        PAGE    1

      PROGRAM HMMOD(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      COMMON/DAD/YS(13),Y(13),YEST(13),DIF(13),DELT(13),TITLE(5),AD(13),
     1A(13),BETA,ALPHA
      COMMON/RAD/DEV(13)
      COMMON/FAD/N
      COMMON/SUM/SX(13),SXY(13)
      COMMON/SQ/SQX(13)
      COMMON/AVE/SDEVA(13)
      REAL DEVA(13)
      WRITE(6,12)
   12 FORMAT(1H1,'  ***  START OF JOBS  ***  ')
      DO 108 IY = 1,10
      READ(5,109) N
  109 FORMAT(I2)
      READ(5,110) (YS(J),J = 1,13)
  110 FORMAT(7F10.0)
      DO 142 IL = 1,13
      SX(IL) = 0.0
      SQX(IL) = 0.0
      SXY(IL) = 0.0
      SDEVA(IL) = 0.0
  142 CONTINUE
      DO 10 IK = 1,N
      READ(5,1)(Y(I),I=1,13)
    1 FORMAT(7F10.0)
      READ(5,11) TITLE
   11 FORMAT(5A10)
      SUM = 0.0
      TOT = 0.0
      J = 0
    2 K = 0
    3 J = J+1
      TOT = TOT+YS(J)
      SUM = SUM+Y(J)
      K = K+1
      IF (K.EQ.6) GO TO 4
      GO TO 3
    4 IF (J.GT.6) GO TO 5
      YA1 = SUM/6.0
      YSA1 =TOT/6.0
      SUM = 0.0
      TOT = 0.0
      GO TO 2
    5 YA2 = SUM/6.0
      YSA2 = TOT/6.0
      BETA = (YA1 - YA2)/(YSA1 - YSA2)
      ALPHA = YA1 -  BETA*YSA1
      DO 6 L = 1,13
      YEST(L) = ALPHA + BETA*YS(L)
      DIF(L) = Y(L) - YS(L)
      DEV(L) = Y(L) - YEST(L)
      SX(L) = SX(L) + DEV(L)
      SQX(L) = SQX(L) + DEV(L)*DEV(L)
      IF (IK.EQ.1) AD(L) = DEV(L)
      A(L) = DEV(L) - AD(L)
      DELT(L) = YS(L) - YEST(L)
      DEVA(L) = ABS(DEV(L))

      SDEVA(L) = SDEVA(L) + DEVA(L)
    6 CONTINUE
      DO 152 IS = 1,12
      SXY(IS) = SXY(IS) + DEV(IS)*DEV(IS+1)
  152 CONTINUE
      CALL WRITER
   10 CONTINUE
      CALL CORDEV
      CALL STANDA
  108 CONTINUE
      STOP
      END

SUBROUTINE WRITER     74/74    OPT=2                              FTN 4.2+ REL        10/08/76  11.19.24.        PAGE    1

      SUBROUTINE WRITER
C THIS SUBROUTINE WRITES OUT THE RESULT OF THE MAIN PROGRAM
      COMMON/DAD/YS(13),Y(13),YEST(13),DIF(13),DELT(13),TITLE(5),AD(13),
     1A(13),BETA,ALPHA
      COMMON/RAD/DEV(13)
      WRITE(6,7)
    7 FORMAT(/// 7X,'    YS      ',9X,'     Y      ',6X,'      YEST      ',7X,
     +'    DIF     ',7X,'     DEV     ',6X,'    DELT    ',9X,'ABSDEV')
      WRITE(6,8)(YS(M),Y(M),YEST(M),DIF(M),DEV(M),DELT(M),A(M),M = 1,13)
    8 FORMAT(7(4X,F10.5,5X))
      WRITE(6,9) BETA,ALPHA,TITLE
    9 FORMAT(/10X,'BETA =',F10.5,5X,'ALPHA =',F10.5,5X,5A10)
      RETURN
      END

SUBROUTINE CORDEV     74/74    OPT=2                              FTN 4.2+ REL        10/08/76  11.19.27.        PAGE    1

      SUBROUTINE CORDEV
C THIS SUBROUTINE CALCULATES PRODUCT MOMENT CORRELATION COEFFICIENT
      COMMON/FAD/N
      COMMON/SUM/SX(13),SXY(13)
      COMMON/SQ/SQX(13)
      REAL DEN(13),SQDEN(13),CORR(13),SN(13)
      DO 148 IC = 1,12
      KC = IC + 1
      SN(IC) = SXY(IC) - (SX(IC)*SX(KC))/N
      DEN(IC) = (SQX(IC)-SX(IC)*SX(IC)/N)*(SQX(KC)-SX(KC)*SX(KC)/N)
      SQDEN(IC) = SQRT(DEN(IC))
      CORR(IC) = SN(IC)/SQDEN(IC)
  148 CONTINUE
      WRITE(6,147)(SX(M),SQX(M),SXY(M),SN(M),DEN(M),SQDEN(M),CORR(M),M =
     11,13)
  147 FORMAT(//7(3X,F13.10))
      RETURN
      END

SUBROUTINE STANDA     74/74    OPT=2                              FTN 4.2+ REL        10/08/76  11.19.30.        PAGE    1

      SUBROUTINE STANDA
C THIS SUBROUTINE CALCULATES STANDARD DEVIATIONS
C     AND AVERAGE ABSOLUTE DEVIATIONS
      COMMON/AVE/SDEVA(13)
      COMMON/SQ/SQX(13)
      COMMON/FAD/N
      REAL ADEVA(13),STAND(13)
      DO 170 IO = 1,13
      STAND(IO) = SQRT(SQX(IO)/N)
      ADEVA(IO) = SDEVA(IO)/N
  170 CONTINUE
      WRITE(6,169)(SQX(M),STAND(M),SDEVA(M),ADEVA(M),M= 1,13)
  169 FORMAT(//4(3X,F12.7))
      RETURN
      END
```

Computer Program No.4 used in the application of the Three-Census Method, in Chapter 5

```
PROGRAM TRICENS    74/74    OPT=2                    FTN 4.2+ REL        07/11/75  10.51.39.      PAGE    1

      PROGRAM TRICENS(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      REAL A(15),B(15),C(15),P(15),XP(15),S(15),XS(15),R(15),XR(15),YR(1
     15),ZR(15),ALPHA(15),X2(15),X3(15),X5(15),X6(15),X8(15),X10(15),X11
     1(15),SR(15),VR(15),X12(15),X13(15),X7(15)
      DO 199 MX = 1,6
      READ(5,200)X,Y,Z
  200 FORMAT(A2,2X,A2,2X,A2)
      WRITE(6,4)X,Z
    4 FORMAT(1H0//19X,'THE TECHNIQUE OF THREE SUCCESSIVE CENSUSES - TURK
     1ISH FEMALES - 19',A2,'-19',A2)
      READ(5,6) FIRSTK,UPDATE
    6 FORMAT(2F10.0)
      READ(5,10) A,B,C,P,XP
   10 FORMAT((8F10.0/7F10.0))
   15 X3(1) = 1.
      SUMA = 0.
      SUMB = 0.
      SUMC = 0.
      SUMX5 =0.
      SUMX7 = 0.
      SUMX10 = 0.
      SUMX13 = 0.
      DO 20 I = 1,14
      J = I+1
      S(I) = B(J)/A(I)
      R(I) = S(I)/P(I)
      YR(I) = R(I)
      IF(I .GT. 1) YR(I) =YR(I-1)*R(I)
      SR(I) = R(I)**2
      VR(I) = SR(I)
      IF(I .GT. 1) VR(I) = SR(I) * YR(I-1)
      XS(I) = C(J)/B(I)
      XR(I) = XS(I)/XP(I)
      ZR(I) = XR(I)
      IF(I .GT. 1) ZR(I) = ZR(I-1)*XR(I)
      ALPHA(I) = VR(I)/ZR(I)
      X2(I) = ALPHA(I)/FIRSTK
      X3(J) = X2(I)* X3(I)
   20 CONTINUE
      DO 30 N=1,15
      X5(N) = A(N)/X3(N)
      SUMA = SUMA + A(N)
      SUMX5 = SUMX5 + X5(N)
   30 CONTINUE
      X6(1) = SUMX5/SUMA
      DO 40 M = 1,15
      SUMB = SUMB + B(M)
      X6(M) = X6(1) * X3(M)
      X7(M) = A(M)/X6(M)
      SUMX7 = SUMX7 + X7(M)
      L = M + 1
      IF(L .GT. 15) GO TO 40
      X8(L)= P(M)*X6(M)
      X10(L) = B(L)/X8(L)
      SUMX10 = SUMX10 + X10(L)
   40 CONTINUE
      X10(1) = SUMB - SUMX10

      TOT10 = SUMX10 + X10(1)
      X8(1) = B(1)/X10(1)
      ESTK = X8(1)/X6(1)
      DO 50 I = 1,15
      X11(I) = XP(I)**2
      X12(I)=X11(I)/X6(I)
      X13(I) = C(I)/X12(I)
      SUMC = SUMC + C(I)
      SUMX13 = SUMX13 + X13(I)
   50 CONTINUE
      FIRSTK = FIRSTK + UPDATE
      IF(FIRSTK .GE. ESTK) GO TO 120
      GO TO 15
  120 WRITE(6,100)X,Y,Z,X,Y,Y,Z,X,Y,Y,Z,X,Y,Y,Z,X,Y,Y,Z
  100 FORMAT(1H0///43X,'SURVIVORSHIP RATES'//10X,'ENUMERATED POPULATION'
     1,6X,'LIFE TABLE RATES',4X,'OBSERVED RATES',4X,'RATIO-OBSERVED/LIFE
     1',3X,'CHAINED RATIOS'///2X,'INDEX',3(5X,'19',A2),8(3X,'19',A2,'-',A
     12))
      WRITE(6,60)(M,A(M),B(M),C(M),P(M),XP(M),S(M),XS(M),R(M),XR(M),YR(M
     1),ZR(M),ALPHA(M),M = 1,15)
   60 FORMAT(1H ,4X,I2,4X,F6.1,3X,F6.1,3X,F6.1,3X,F7.5,3X,F7.5,3X,F7.5,3
     1X,F7.5,3X,F7.5,3X,F7.5,3X,F7.5,3X,F7.5)
      WRITE(6,110)X,X,X,Y,Y,Z,Z
  110 FORMAT(1H0///3X,'INDEX',24X,'19',A2,12X,'ALPHA',4X,'EST19',A2,2X,'
     1P(19',A2,')',4X,'BETA',6X,'19',A2,3X,'EST19',A2,6X,'GAMA',6X,'19',
     1A2,4X,'EST19',A2)
      WRITE(6,70)(I,X2(I),X3(I),A(I),X5(I),X6(I),X7(I),B(I),X8(I),B(I),X
     110(I),X12(I),C(I),X13(I),I = 1,15)
   70 FORMAT(1H ,4X,I2,3X,F7.5,3X,F7.5,4X,F6.1,3X,F6.1,2X,F7.5,3X,F6.1,2
     1X,F7.5,2X,F7.5,4X,F6.1,4X,F6.1,3X,F7.5,4X,F6.1,4X,F6.1)
      WRITE(6,80)SUMA,SUMX5,SUMX7,SUMB,TOT10,SUMC,SUMX13
   80 FORMAT(1H0//2X,'TOTAL',22X,F8.1,1X,F8.1,10X,F8.1,21X,F8.1,2X,F8.1,1
     11X,F8.1,2X,F8.1)
      WRITE(6,90) FIRSTK,ESTK
   90 FORMAT(1H0/20X,'ORIGINAL VALUE OF K =',2X,F12.10,10X,'ESTIMATED VA
     1LUE OF K = ',2X,F12.10)
  199 CONTINUE
      STOP
      END
```

Computer Program No.5 used in the application of the New-Two-Census Method - the Period-Age-Interval Method - in Chapter 6.


```
      PROGRAM BICENS(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      REAL A(16),B(16),C(16),R(16),S(16),D(16),ETA(17),TF(16),TL(16)
      WRITE(6,60)
   60 FORMAT(1H0//20X,'REAL FLUCTUATIONS IN TURKISH FEMALE AGE DATA OF 1
     1965 AND 1970 CENSUSES '///4X,'INDEX ',4X,'1965 ',5X,'1970 ',2X,'RA
     1TIO1965/70 ',2X,'CHAINEDRATIO ',2X,'SMOOTHE ',4X,'D ',3X,'REAL FLU
     1CTUATION ',2X,'TRUE1965 ',2X,'TRUE1970 ')
      SUMS = 0.0
      SUMD = 0.0
      READ(5,10)A,B,S
   10 FORMAT(8F10.0/8F10.0)
      DO 20 I = 1,16
      C(I) = A(I)/B(I)
      R(I) = C(I)
      IF(I .GT. 1) R(I) = R(I-1)*C(I)
   20 CONTINUE
      DO 80 J = 1,16
      D(J) = S(J)
      IF(J .GT. 1) D(J) = R(J-1)*S(J)
      SUMS = SUMS+S(J)
      SUMD = SUMD+D(J)
   80 CONTINUE
      ETA(1) = SUMD/SUMS
      DO 40 L = 1,16
      M = L+1
      ETA(M) = ETA(1)*R(L)
      TF(L) = S(L)*ETA(M)
      TL(L) = S(L)*ETA(L)
   40 CONTINUE
      DO 70 K = 1,16
      WRITE(6,50)K,A(K),B(K),C(K),R(K),S(K),D(K),ETA(K),TF(K),TL(K)
   50 FORMAT(1H0,5X,I2,5X,F5.2,5X,F5.2,5X,F9.6,5X,F9.6,5X,F5.2,5X,F5.2,5
     1X,F9.6,7X,F5.2,7X,F5.2)
   70 CONTINUE
      STOP
      END
```

Computer Program No.6 used in the application of the Extended Method, in Chapter 6

```
PROGRAM DINT        74/74    OPT=1                 FTN 4.0+P357      08/05/75  17.27.39.      PAGE    1

         PROGRAM DINT (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
         REAL A(16),B(16),R(16),PI(16),ETA(16)
         WRITE(6,90)
   90    FORMAT(1H1,3X,'A TECHNIQUE OF USING TEN-YEAR INTER-CENSAL DATA ON
        1THE BASIS OF FIVE YEAR AGE GROUPS - TURKISH FEMALES ')
         DO 200 IX = 1,5
         READ(5,80)X,Y
   80    FORMAT(A4,2X,A4)
         READ(5,100) A,B
  100    FORMAT((8F10.0/8F10.0))
         DO 110 I =1,16
         R(I) = A(I)/B(I)
  110    CONTINUE
         PI(1) = R(1)
         PI(2) = R(2)
         DO 120 I = 3,16,2
         PI(I) = R(I) *PI(I-2)
         DO 120 M = 4,16,2
         PI(M) = R(M) *PI(M-2)
  120    CONTINUE
         SUMPI1=0.0
         DO 130 I = 1,16,2
         SUMPI1 = SUMPI1 + PI(I)
  130    CONTINUE
         SUMPI2=0.0
         DO 135 M = 2,16,2
         SUMPI2 = SUMPI2 +PI(M)
  135    CONTINUE
         GAMA = (SUMPI2-SUMPI1)/(SUMPI1 + SUMPI2)
         X1 = GAMA + 1.0
         X2 = 1.0-GAMA
         DO 140 I =1,15,2
         DO 140 M = 2,16,2
         ETA(I) = PI(I)*X1
         ETA(M) = PI(M)*X2
  140    CONTINUE
         WRITE(6,180) X,Y
  180    FORMAT(1H0,2X,'INDEX',4X,A4,4X,A4,6X,'R',10X,'PI',9X,'ETA')
         DO 150 N = 1,16
         WRITE (6,160) N,A(N),B(N),R(N),PI(N),ETA(N)
  160    FORMAT (1H ,4X,I2,4X,F5.2,3X,F5.2,3X,F8.6,3X,F8.6,3X,F8.6)
  150    CONTINUE
         WRITE(6,170) X1,X2,SUMPI1,SUMPI2
  170    FORMAT(1H0/5X,'1+GAMA= ',3X,F8.6,3X,'1-GAMA= ',3X,F8.6,3X,' FIRST
        1SUM OF PI = ',3X,F10.6,3X,'SECOND SUM OF PI= ',3X,F10.6)
  200    CONTINUE
         STOP
         END
```

BIBLIOGRAPHY

OFFICIAL REPORTS

1. BOTSWANA: Report of the Population Census 1971. Republic of Botswana, Central Statistics Office, Government Printer. August 1972.

2. FIJI: Colony of Fiji: A Report on the Results of the Population Census 1946, Government Printer, Suva, Fiji, 1947.

3. ——: Colony of Fiji, A Report on the Census of the Population, 1956, Government Printer, Suva, Fiji, 1957.

4. ——: Colony of Fiji, A Report on the Census of the Population, 1966, Government Printer, Suva, Fiji, 1967.

5. GHANA: 1960 Population Census of Ghana, Volume V, General Report by B. Gil and K.T. De Graft-Johnson, Census Office, Accra, 1964.

6. ——: 1970 Population Census of Ghana, Volume 1, Statistics of Localities and Enumeration Areas, Census Office, Accra, June 1972.

7. KENYA: Kenya Population Census 1962, Volume III, African Population, Statistics Division, Ministry of Economic Planning and Development, October 1966.

8. LESOTHO: 1966 Population Census Report, Kingdom of Lesotho, Volume 1, Bureau of Statistics, P.O. Box 455, Maseru, Lesotho.

9. MAURITIUS: 1972 Population Census of Mauritius, Volume 1, Preliminary Report. Mauritius Central Statistics Office, 1974.

10. RHODESIA: 1969 Population Census, Interim Report, Volume II, The African Census. Central Statistical Office, Salisbury, Rhodesia, February 1971.

11. SWAZILAND: Report on the 1966 Swaziland Population Census, by H.M. Jones, Published by Swaziland Government, Mbubane 1968.

12. TANZANIA: The Republic of Tanzania 1967 Population Census, Volume II, Statistics for Urban Areas, Bureau of Statistics, Ministry of Economic Affairs and Development Planning, Dar Es Salaam, 1970.

13. TURKEY: Census of Population 25 October 1970, Sampling Results, Republic of Turkey, Prime Ministry, State Institute of Statistics Printing Division, Ankara, 1972.

14. UGANDA: Uganda Census 1959, African Population, Statistical Branch, Government Printer, Entebbe, 1961.

15. ———: Report on the 1969 Population Census, Volume 1: The Population of Administrative Areas, The Statistical Division, Ministry of Planning and Economic Development, Government Printer, Entebbe, November 1971.

16. UNITED NATIONS: Demographic Year Books, 1950 to 1974, United Nations, New York.

17. ———: Age and Sex Patterns of Mortality. Model Life-Tables for Under-developed Countries. (Population Studies, No.22). New York, 1955.

18. ———: Methods of Appraisal of Quality of Basic Data for Population Estimates. Manual II (Population Studies No.23). New York, 1955.

19. ———: Manual III - Methods for Population Projections by Sex and Age. (Population Studies No.25). New York, 1956.

20. ———: The Mysore Population Study. Department of Economic and Social Affairs. (Population Studies No.34). New York, 1961.

21. ———: Population Bulletin No.6. New York, 1963.

22. ———: Manual IV - Methods of Estimating Basic Demographic Measures for Incomplete Data. (Population Studies No.42). New York, 1967.

23. ———: The Concept of a Stable Population. (Population Studies No.39). New York, 1968.

24. U.S.A.: The Methods and Materials of Demography, Vols.1 and 2, Shryock, H.S., and Siegel, J., ,U.S. Department of Commerce, Bureau of the Census, Washington, 1973.

25. ZAMBIA: Republic of Zambia: Census of Population and Housing 1969. First Report. Central Statistical Office, Lusaka, August 1970.

26. ———: Republic of Zambia: Census of Population and Housing 1969. Final Report, Vol.1. Central Statistical Office, Lusaka, November 1973.

AUTHORS

1. BACHI, R. 'The Tendency to Round Off Age Returns: Measurement and Correction". Bulletin of the International Statistical Institute, 33(4); 195-221. International Statistical Conference, India, December 1951.

2. ————: 'Measurement of the Tendency to Round Off Age Returns'. Bulletin de l'Institut International de Statistique (Procs. 28th Session, Rome, September 6-12, 1953) 34(3), 129-138, 1954.

3. BERNADELLI, H. 'Population Waves', Journal of the Burma Research Society, Vol.XXI Part 1,(April 1941).

4. BLACKER , J.G.C. 'Some unsolved problems of census and demographic survey work in Africa', in Procs. of the International Population Conference, London 1969, Vol.1. pp.227-285. Liege, IUSSP.

5. BLACKER, J.G.C. and SCOTT, C. Manual on Demographic Sample Surveys in Africa, United Nations Economic Commission for Africa, September 1974.

6. BOURGEOIS-PICHAT, J. The Concept of a Stable Population, Application to the Study of Populations of Countries with Incomplete Demographic Statistics, Department of Economic and Social Affairs, (Population Studies, No.39), U.N., New York, 1968.

7. BRASS, W. 'Disciplining demographic data', Procs. of the International Population Conference, London, 1969, Vol.I. Liege, IUSSP.

8. ——: 'On the Scale of Mortality', Biological Aspects of Demography, Taylor and Francis Ltd., London, 1971.

9. ——: Methods for Estimating Fertility and Mortality from Limited and Defective Data. University of North Carolina, Chapel Hill, U.S.A. October 1975.

10. ——: 'A Note on Empirical Mortality Models'. A Working Paper presented at the U.N. Group of Experts Meeting, 8-12 December, 1975. New York.

11. BRASS, W. et al. The Demography of Tropical Africa. Princeton: Princeton University Press, 1968.

12. BRASS, W. and HILL, K. 'Estimating Adult Mortality from Orphanhood'. Procs. of the International Population Conference, 1973, Liege, IUSSP.

13. CALDWELL, J. and IGUN, A.A., 'An Experiment with Census-type Age Enumeration in Nigeria'. Population Studies, Vol.25, No.2. July 1971.pp.287-302.

14. CARRIER, N.H., 'A Note on the Measurement of Digital Preference'. Journal of the Institute of Actuaries, Vol.85, 1959. pp.71-85.

15. CARRIER, N.H. and FARRAG, A.M. 'The Reduction of Errors in Census Populations for Statistically Underdeveloped Countries'. Population Studies, Vol.XII, No.3. March 1959.

16. CARRIER, N.H. and HOBCRAFT, J. Demographic Estimation for Developing Societies. Population Investigation Committee, London 1971.

17. CELEBIOGLU, A.T. Mortality and Fertility in Turkey 1960-70, A Comparison between Turkish Demographic Survey and Population Census. MSc. Dissertation, University of London, October 1974.

18. COALE, A.J. 'How the Age Distribution of a Human Population in Determined', Cold Spring Harbor Symposia on Quantitative Biology, Vol.XXII (1957). pp.83-99.

19. ——: The Growth and Structure of Human Populations, A Mathematical Investigation. Princeton, New Jersey, Princeton University Press, 197

20. COALE, A.J. and DEMENY, P. Regional Model Life Tables and Stable Populations. Princeton University Press, 1966.

21. COALE, A.J. and DEMENY, P. Methods of Estimating Basic Demographic Measures for Incomplete Data, U.N. Manual IV (Population Studies No.42), New York, 1967.

22. CONDE, J. The Demographic Transition as Applied to Tropical Africa, with particular reference to Health, Education and Economic Factors. O.E.C.D. Development Centre, Paris, August 1971.

23. DAS GUPTA, P. 'A General Method of Correction for Age Misreporting in Census Populations', Demography, Vol.12, No.2. May 1975.

24. DEMENY, P. and SHORTER, F.C. 'Estimating Turkish Mortality, Fertility and Age Structure'. Istanbul University Press. Istanbul 1968.

25. GABRIEL, K.R. and RONEN, I. 'Estimates of Mortality from Infant Mortality Rates, Population Studies, Vol.XII, No.2. November 1958.

26. GAISIE, S.K. Determinants of Population Growth in Ghana, PhD. Thesis, Australian National University, Canberra, February 1973.

27. GIBRIL, M.A. Some Reporting Errors in the 1973 Gambian Census. MSc. Dissertation, University of London, 1975.

28. GRAUMAN, J. 'Attempt at adjustment of severely inaccurate age statistics: Countries of Tropical Africa'. E/CN.14/POP/94: Seminar on Techniques of Evaluation of Basic Demographic Data, Accra, Ghana, July 1973.

29. HICKS, W.W. 'Economic Development and Fertility Change in Mexico'. Demography Vol.11, No.3. August 1974.

30. HILL, K. Indirect Methods of Estimating Adult Mortality Levels. PhD. Thesis. University of London, 1975.

31. HILL, K. and TRUSSELL, J. Further Developments in Indirect Mortality Estimation. Population Studies, ~~March~~ July 1977 (forthcoming).

32. KARADAYO, F. 'Population Growth in Turkey'. In: The Population of Turkey:

33. KPEDEKPO, G.M.K. 'The Extent and Nature of Errors in the 1960 Ghana Census'. Journal of the West African Science Association, Vol.12, No.2. 1967.

34. MYERS, R.J. 'Errors and Bias in the Reporting of Ages in Census Data'. Transactions of the Actuarial Society of America. Vol.XLI, Part 2, No.104, October 1940. pp.395-415.

35. ————: 'The Accuracy of Age Reporting in the 1950 US Census'. Journal of the American Statistical Association, Vol.49. pp826-831. December 1954.

36. ————: 'An Instance of Reverse Heaping of Ages'. Demography, Vol.13. No.4. November 1976.

37. NTOZI, J.P.M. 'The Patterns and Levels of Fertility for Africans in Uganda 1948-69'. MSc. Dissertation, Makerere University. Kampala, 1973.

38. RAMACHANDRAN, K.V. 'An Index to Measure Digit Preference Error in Age Data'. U.N. World Population Conference, Belgrade, 1965.

39. SELTZER, W. Demographic Data Collection, A Summary of Experience. An Occasional Paper of the Population Council, New York, 1973.

40. SHAW, D.C. and JOHNSON, D.M. Demographic Computer Library. Technical Paper of the U.S. Department of Commerce, Bureau of Census. June 1971.

41. SHORTER, F.C. and GUVENC, B.(ed.) Turkish Demography. Procs. of a conference sponsored by the Institute of Population Studies, Hacettepe University. (Izmir , February 21-24, 1968). Publication No.7, Ankara, 1969.

42. SHORTER, F.C. and PASTA, D. Computational Methods for Population Projections with a Particular Reference to Development Planning. The Population Council, New York, 1974.

43. SPRAGUE, T.B. 'Explanation of a New Formula for Interpolation'. Journal of

44. VAN de KAA, D.J. The Demography of Papua and New Guinea's Indigenous Population. PhD. Thesis, Australian National University, Canberra, 1971. Chapter IV.

45. VAN de WALLE, E. 'Characteristics of African Demographic Data'. In: The Demography of Tropical Africa. by Brass, W. et al. Princeton University Press, 1968.

46. VOORS, A.W. 'The Use of Dental Age in Studies of Nutrition in Children'. Documenta de Medicina Geographica et Tropica. Vol.9. pp.137-148. 1957.

47. VOORS, A.W. and METSELAAR, D. 'The reliability of dental age as a yardstick to assess the unknown calendar age'. Tropical and Geographical Medicine. Vol.10. pp.175-180. 1958.

48. XENOS, C. Fertility Change in Mauritius and the Impact of the Family Planning Programme. PhD. Thesis, University of London. 1976.

49. ZELNIK, M. 'Age Heapings in the U.S. Census; 1880-1950'. Milbank Memorial Fund Quarterly 39(3): pp.540-573. July 1961.