INTERCENSAL FERTILITY ESTIMATION IN KENYA.

by

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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DEDICATION.

To my grand mothers, those great ladies,
Sabina and Maria.

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ABSTRACT OF THE THESIS.

This study examines indirect techniques of estimating intercensal fertility levels in Kenya. Parameters, Crude birth Birth Rate, Total Fertility Rate, Net Reproduction Rate, Gross Reproduction Rate and the Mean Age at Birth for the 1969 to 1979 intercensal period are estimated at National, provincial and district levels. These are estimated by applying several standard indirect procedures and models of estimating fertility which are also compared. To obtain estimates that reflect effects on a hypothetical cohort of a prolonged exposure to vital rates in operation during the 1969 to 1979 intercensal period, the standard procedures are adjusted by the additive synthetic adjustment technique. The age-specific growth rate adjustment technique, functioning as both an indirect procedure and an adjustment technique, is also used to estimate fertility parameters that reflect exposure of a hypothetical age cohort to past rates of attrition and entry into the population. This also reflects, among other things, the effect of vital rates and migration rates prevailing during the 1969 to 1979 intercensal period. The techniques have also been applied in evaluation of data quality.

Chapter One introduces the study by stating the problem, objectives of the study, significance of the study, literature on historical and technical backgrouds of techniques, sources and quality of data and definitions of parameters. Chapter Two discusses P/F ratio methods, namely the Brass and Coale-Trussell P/F ratio methods. Chapter Three examines techniques

that base estimations on only reported lifetime fertility, namely the Coale-Demeny $P3^2/P2$ formula, and Brass-Rachad's $P2(P4/P3)^4$ formula. Chapter Four Describes and discusses the relational Gompertz model. Chapter Five discusses the age-specific growth rate adjustment technique. Chapter Six gives a summary of the findings, conclussions and recommendations. This is followed by references/bibliography and appendices.

National, provincial and district level analysis shows that indirect techniques that estimate intercensal fertility levels in the presence of trends donot perform as well as those that rely only on lifetime fertility data. Also evident is the disparity between data on births reported in the twelve months peceeding each census and data reported by the same women regarding the number of children ever born. Synthesising data to refer to hypothetical cohorts theoreticaly minimises the effects of intercensal changes in vital rates and patterns of error on fertility estimates for the same period. But, still, additive synthetic adjustment technique amplifies the margin of error created by such changes. Also, the age-specific growth rate adjustment technique is reliable only if changes in the composition of age cohorts are adequately adjusted for. The latter is especially sensitive to effects of migration.

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CHAPTER ONE

1.1. INTRODUCTION.

In situations where conventional vital statistics are lacking or thought to be inadequate, techniques that use indirect evidence from cross-sectional reports or retrospective data are useful in the estimation of fertility parameters. These may be in form of evidence about age and sex composition of the population from censuses or surveys; intercensal natural growth between enumerations of the same population; or about fertility from responses to questions on previous births, children who have died among those that have been born and recent births occuring twelve months , say, preceding the enumeration (Brass and Coale, 1968).

Some aproaches to estimating fertility events in the absence of reliable registration data have been widely discussed.(1) These have included, inter alia, estimation of vital events by applying model stable and quasi-stable populations, or model lifetables to census/survey data. Other techniques have sought retrospective information which, with certain assumptions based on demographic principles and true experiences drawn from certain populations have proved useful in generating fertility parameters.

These techniques that rely on retrospective information, such as the Brass-type methods are oftentimes used to derive aggregate fertility measures. This is characteristic of previous works on fertility estimation in Kenya which have mainly concentrated on estimating the total fertility rate (Som,1968;Van de Walle,1968;Kangi,1977; Abagasi,1977; Henin,1979; Anker and Knowles,1980; Mwobobia, 1982).

In this study we shall endeavour to not only obtain, for the first time, intercensal fertility estimates for the 1969-1979 period, but also to estimate other fertility parameters besides the total fertility rate.

Retrospective information drawn from the 1969 and 1979 censuses in the form of numbers of children born in the past, of children who have hence died, and of live births in the twelve months preceding each census shall be employed in this study. However, these will require preliminary adjustment for the intercensal period before the various techniques are applied to them. The additive synthetic technique shall be used for such adjustment.

Preston and Coale (1982) developed a useful technique that estimates the intercensal birth rate, net reproduction rate, gross reproduction rate, total fertility rate and the mean age at birth - with or without due regard to the maternal mortality schedule. The techique, itself a tool of adjustment, relies only on model lifetables and the age distribution of the population. For lack of complete vital registration in Kenya or reliable vital registration data such an undemanding technique is deemed quite promising, and has been chosen to be one of the major object of this study. Although it has not been tested on Kenya's data it has a sound demographic basis.

In particular, aspects of intercensal fertility estimation shall be examined by way of discussing the performance of the above technique, the Brass and Coale-Trussell P/F Ratio methods, Coale-Demeny's P_3^2/P_2 and Brass-Rachad's $P_2(P_4/P_3)^4$ formulae and the relational Gompertz model.

Other techniques that estimate the net reproduction rate, the gross reproduction rate and the total fertility rate by using age distributions are regression methods.[2] Their utility in fertility estimation - so far mainly tested in Asia and the Pacific - is yet to be proven by additional testing, and shall be excluded from this exercise.

The methodological approach used in this study shall not be the traditional statement and verification of hypotheses. Rather, this purely technical work is thought to be best served if any hypothesis that may be formulated is generated from data rather than basing it on previously stated theories. For this reason, clearer appreciation of the theoretical frameworks is thought to be best achieved if these are discussed within the the various techniques they are relevant to.

1.2. STATEMENT OF THE PROBLEM.

Several methods have been proposed for rehabilitating, developing and making use of incomplete or unreliable demographic data for estimation. The propriety of using these methods largely depends on the scope and specificity of available information (Brass,1975). Censuses and surveys in Kenya tend to generate data whose quality limits fertility estimation to indirect techniques, as will be apparent in the literarure review. Most of the techniques have relied on retrospetive data.

Little has been done with alternative methods that rely, for instance, on the populations age distribution or model stable populations or life tables. There is need to examine these with a view to estimating fertility parameters for comparison with the more common methods. Previous estimation methods have not taken into account the effect of other population components on fertility levels and patterns. Techniques that consider the effect of mortality (through the use of life tables), or of migration (through the use of age-specific migration rates) are indeed called for. So are those that can estimate other parameters other than the total fertility rate.

Intercensal fertility estimation with Kenya's census data is a novel idea. Rarely has the dynamism of fertility between two points of time been captured. The application of the age-specific growth rate technique or the additive synthetic adjustment procedure, for example, to Kenya's data covering two censuses simultaneously has not been documented. Census data employed in measurements and estimations have been drawn from individual censuses and analysed separately.

1.3. OBJECTIVES OF THE STUDY

The following are the objectives of this study:

(1) To estimate intercensal fertility measures using other parameters besides the total fertility rate, namely: the birth rate, the net reproduction rate, the gross reproduction rate, and the mean age at birth at the national, provincial, and district levels.

(2) To compare various methods of measuring intercensal fertility in Kenya, namely:

(a) The Brass(1968) and the Coale-Trussell(1974) P/F Ratio methods with the additive synthetic adjustment technique;

(b) Coale-Demeny's (United Nations,1967) $P3^2/P2$ and Brass-Rachad's (1979) $P2(P4/P3)^4$ procedures with the additive synthetic adjustment technique;

(c) The relational Gompertz model(Brass,1968) with the additive synthetic adjustment technique; and

(d) The age specific growth rate technique (Preston and Coale,1982).

(3) To use some of the above techniques to detect types of, or patterns of error that may afflict Kenya's census data.

1.4. SIGNIFICANCE OF THE STUDY

Fertility measures need to be revisited whenever new or improved versions of techniques and models of data analysis supplant earlier ones. This is not only for the reason that fertility is a dynamic process that needs constant re-examination, but also because no single technique or model can claim to function universally in all situations. There is, thus, much to gain in comparing the performance of, as well as estimates obtained by different techniques.

One principle in developing demographic estimates is to use whatever information that is available to generate reasonable estimates. The ideal situation, perhaps, would be the availability of complete and reliable vital registration data for the whole country. The data that exists necessitates placing a lot of confidence in the major censuses, in particular the 1969 and 1979 censuses. But we need to approximate trends and levels of fertility by correcting as little data as possible to minimise the risk of over-adjustment. Indirect techniques, such as the ones considered in the study, should put to use a wealth of census information.

Considerable changes are expected to have occured in Kenya's fertility between the 1969 and 1979 censuses. Intercensal estimation takes into account such changes. Besides, it facilitates analysis of fertility data drawn from two censuses with minimal duplication of deficiencies that may be unique to each census. Of course, the design and execution of each census gives rise to unique data errors, and one type or pattern of error in one census by no means nullifies another type of error in the other census. However, the use of two censuses is expected to smooth out certain types of error in data, for instance changes in the pattern of age misreporting. The age-specific growth rates (which will be useful in estimating most of the fertility parameters) would, for example, be unaffected by constant proportionate distortions at the first and second censuses.(3)

Exploring the performance of various intercensal techniques should illuminate potential methodological study areas, given the wide interval between censuses, that might in future necessitate intersurvey estimation.

1.5 LITERATURE REVIEW

1.5.1. Introduction.

Literature on fertility estimation and measurement has several examples of attempts to devise approaches to estimating events in the absence of reliable registration data. As already noted, the (robustness of) various methods that have been proposed will depend on the scope of, and the specificity of available information. Errors or patterns of distortion from such information are likely to be unique to local conditions. Futhermore, "...it is a mistake to assume that different populations have the same age pattern of fertility - even populations not employing contraception or abortion".[4] Since no method functions universally in all conditions, and it is almost impossible to anticipate patterns of errors (Brass,1975), it may not be useful or relevant to dwell on literature dealing with non-Kenyan situations in fertility estimation and measurement.

1.5.2. The P/F Ratio Methods.

Estimation of fertility in Kenya has in many cases been based on the P/F ratio methods. The methods are a means of adjusting the level of observed age-specific fertility rates by attempting to rectify the reference period error in the latter. They use a polynomial function model (Brass,1968):

$$f(a) = c(a-s)(s+33-a)^2 , \quad s < a < s+33 \qquad (1.5.1)$$

where f(a) is the age-specific fertility rates form women aged a, c is a constant and s is the starting age of childbearing.

This function estimates the F(i) values. Cumulated fertility up to age a is obtained by the integral of f(a) from s to a. P(i) values represent the average number of children ever born. The P(i)/F(i) ratios obtained from both "retrospective" and "current" fertility are thought to combine the most accurate information on the level and pattern of fertility and are used to adjust the age-specific fertility rates.

Brass(1968) observed that the use of a general polynomial in describing distributions of age-specific fertility was cumbersome because of several terms, and therefore parametres were required to obtain a good fit to the observations. Coale and Trussell (1974) proposed fitting a second degree polynomial to three consecutive values of the cumulated fertility schedule, Q(i), and estimating the average parity of women by evaluating the integral of the polynomial. That is:

$$Q(i) = \sum_{i=1}^{7} f(i). \qquad (1.5.2)$$

The average parity eqivalents are then estimated by:

$$F(i) = Q(i-1) + a(i)f(i) + b(i)f(i+1) + c(i)Q(7), \qquad (1.5.3)$$

where i = 1 through 6, and

$$F(7) = Q(6) + Q(7)f(6) + b(7)f(7), \qquad (1.5.4)$$

and a,b and c are constants.

Both the Brass and the Coale-Trussell P/F ratio methods operate on the principle of comparing cumulated period fertility with lifetime fertility to estimate the total fertility rate. They only differ in the coefficients and procedures used to estimate the cumulated period fertility, F(i). The Brass method estimates F(i) by:

$$F(i) = 5\sum_{i=1}^{7} f(i)k(i) \qquad (1.5.5)$$

where k(i) are multiplying factors derived by interpolation from multiplying factors provided by the United Nations Social and Economic Affairs Division.(5) The basis of the P/F ratio methods is discussed in Chapter Two.

Osiemo(6) applied the Coale-Trussell method to Kenya's data, employing the 1969 and 1979 censuses. He estimated total fertility by "k1", "k2", "ka" and "kmean", where

k1 = P2/F2,

k2 = P3/F3,

$ka = (P2/F2 + P3/F3)/2$

and $kmean = (P1/F1 + P2/F2 + \ldots, + P7/F7)/7$ (1.5.6)

The model tended to give high values possibly because it assumes under-reporting of fertility events. Values obtained by "kmean" were said to be prefered since they were the lowest.

Som (1968), using the Brass P/F ratio method, estimated total fertility rate for Kenya to be 6.4 children per woman from the 1962 census. Van de Walle (1968) did a similar study, while Blacker (1971) also estimated Kenya's total fertility rate at 7.6 children per woman using the 1969 census. Anker and Knowles (1980) estimated the same to be 8.1, using the National Demographic Survey (1977) data. Many other researchers (Kangi,1977; Henin,1979; Abagasi,1977; Mwobobia,1982; Omagwa,1986) have employed the P/F ratio methods to study Kenya's fertility.

Mwobobia (1982), using 1979 provisional census results found (in common with other studies) that those values of P(i)/F(i) ratios that were closer to unity belonged to higher parities whose use would violate the rationale of the Brass method. For example P2/F2 ratios for Kenya were as high as 1.4801. Usually P2/F2 or P3/F3 ratios are used to adjust age-specific fertility. If they are reasonably consistent either of them can be used as an adjustment factor.

Earlier on, Van de Walle(1968) had used averages of P3/F3 and P4/F4 values. Anker and Knowles (1980), on the other hand, had applied the relation (P4/f4 +P5/F5)/2. Mwobobia argued in support of using ratios of P2/F2 and/or P3/F3, their high values not withstanding: "...due to the tendency of the ratios to fall with age, there exists an age when the ratios can give an adjustment of fertility to a level in conformity with the widely accepted estimate for the country".[6]

Although the P/F ratio methods have been used to estimate fertility at one point in time they have not been applied to Kenya's census data in estimating intercensal fertility.

1.5.3 Coale-Demeny's $P3^2/P2$ and Brass-Rachad's $P2(P4/P3)^4$ Procedures.

One procedure that permits the estimation of the average number of children born to women by the end of their reproductive lifespans was developed by Coale and Demeny using data from Gilbert and Ellice Islands. If P2 and P3 are cumulated fertility rates for women in age groups 20 to 24 years and 25 to 29 years respectively, the relationship between the ratios TF/P3 and P3/P2 is very close (United Nations, Manual Four,1967). Total fertility, estimated from average parities of younger women, is represented by:

$$TFR = P3^2/P2 \qquad (1.5.7)$$

The use of this procedure requires that fertility be relatively constant over the past ten to fifteen years (Arriaga, et al.,1976). The age pattern of fertility should also conform to the typical age relationship found in populations practising little birth control. That is:

(a) The age pattern of declining fecundability is typical, and (b) that widowhood, divorce and other forms of dissolution of sexual unions do not have an unusual age incidence from age 30 to 45 in the population (United Nations,1967).

The procedure is expected to give reasonable total fertility estimates, as it did in its original application to the Gilbert and Ellice Islands. It was, however, found not to be robust when it was applied to West African data (Brass,1975). In Kenya, using 1979 census, Mwobobia(1982) found that the estimates from $P3^2/P2$ were not high enough to be commendable for analysis. For example, Turkana District had total fertility rate of 1.70 children per woman. But, basic data errors aside, this may not be a conclusive appraisal of the procedure: P/F ratio methods against which it was compared have previously tended to over-estimate total fertility, possibly due to their inherent assumption of under-reporting of fertility events.[7]

An alternative formula proposed by Brass (Brass and Rachad,1979) also estimates total fertility from average parities of younger women. If P4 is the average parity for women aged 30 to 34,

$$TFR = P2(P4/P3)^4 . \qquad (1.5.8)$$

Rachad (Brass and Rachad,1979) suggested taking the lower of the two TFR estimates.

The procedures have not been used to estimate intercensal fertility in Kenya from two consecutive censuses.

1.5.4. <u>The Relational Gompertz Model.</u>

The relational Gompretz model of fertility provides a simple tool for adjusting and correcting fertility distributions derived from reports of births in the last year, and/or children ever born (Zaba,1981). The model for fertility proposed by Brass (Brass 1978) is given by:

$$F(x) = T \exp(-\exp(-(a+bYs(x)))) \quad (1.5.9)$$

where F(x) is the cumulated fertility up to age x; T is the total fertility rate;

$$Ys(x) = -\ln(-\ln Fs(x)) \quad (1.5.10);$$

a and b are constants determined by:

$$a+bYs(x) = -\ln(-\ln(F(x)/T)) \quad (1.5.11)$$

and Fs(x) is the standard cumulated fertility to age x, with

$$Ts = 1.0.$$

Also define $P(i) = T \exp(-\exp(-(a+bYs(x))))$, where P(i) is the average parity for the ith five year age group ranging from fifteen years through forty-nine years.

Total fertility can be found directly from data, where a and b can be estimated by relating cumulated fertility, F(x), and average parity,P(i). That is: $-\ln(-\ln F(x)/T)$ and $-\ln(-\ln P(i)/T)$ with the corresponding Ys(x) and Ys(i) values.

Zaba (Zaba 1981) proposed a method that avoids estimation of T directly. The method, known as the **ratio method**, has proved handy in fitting the model to data. "...with most retrospective data from developing countries it is difficult to determine T accurately. Estimates from series of F(x) values are often quite different from those based on series of P(i) values, and both series are less reliable at older ages due to biases in the reporting of births last year and children ever born by older women".[8]

Zaba postulated a relationship between the ratios of successive F(x) and P(i) values, and a and b values required to define a suitable model fertility schedule.

Earlier application of the model in fertility was done by Brass (1974, 1977), Booth (1977) and Brass and Rashad (1980). Brass (1981) applied the relational Gompert model to Kenya data from the 1962 census and the Kenya Fertility Survey of 1977/78. Henin (1979) estimated Kenya's fertility by fitting the model to the data on current fertility of 1976 and 1977 drawn from the 1977 National Demographic Survey. Reported rates for women over forty years of age were excluded as they were considered unrealiable due to age misreporting. Another problem was children living with their grand parents being shown as the offsring of the grandmother. When the model was fitted to the average parities and inflated proportionately to give a total fertility rate of 8.1 it was found to give an exellent fit to the reported values up to the 30 to 34 age group.[9]

Osiemo (1986) applied the model to Kenya data drawn from 1969 and 1979 censuses, separately, to derive estimates for fertility levels and differentials at national, provincial and district levels. He based his total fertility estimates on mean parities, P(i) and their equivalents, F(i). Comparing the model with the Coale-Trussel, the former obtained lower fertility levels. Values based on F(i) were too low due to under-reporting of births. Thus total fertility rates based on P(i) were prefered.

Osiemo, generally, prefered the relational Gompertz model as it adjusts for both under- and over-reporting of births.

The model has not been used to estimate intersensal fertility levels and/or differentials for consecutive censuses in Kenya. It has only been fitted to data drawn from single censuses and surveys.

1.5.5. <u>The Age-specific Growth Rate Technique.</u>

Preston and Coale (1982) introduced the use of population growth rates specific to various five-year age groups in indirect estimation of demographic parameters. This was a welcome extension of the generalised stable population theory, which revolutionised the concept to render it applicable even to non-stable populations.

Previously, the stable and quasi-stable population models gave only approximate estimates (10) and the method based on them was not robust. Either they were used under artificial conditions of constant fertility and certain mortality patterns or for populations where the assumption of stability was not applicable.

From the seminal works of Lotka (Lotka 1907, 1939), the stable population theory was practically applied by the United Nations, Population Division in 1960 , and Coale and Demeny in 1966. Coale (1962) introduced the quasi-stable population theory, assuming constant fertility and declining mortality.

Kenya has been experiencing "rapidly declining mortality and/or fluctuating fertility and thus has undergone a radical departure from stability or quasi-stability. Consequently, previously successful methods based on stable or quasi-stable population theory, are with greater frequency ill suited to the use for which they were devised". (11)

Assuming constant age-specific growth rates, r, the classic equations are (Preston and Coale,1982):

$$c(a) = b\,e^{-ra}\,p(a) \qquad (1.5.12)$$

$$b = 1/\left(\int_0^{\infty} e^{-ra}\,p(a)\,da\right) \qquad (1.5.13)$$

and

$$1 = \int_{\alpha}^{\beta} e^{-ra}\,p(a)\,m(a)\,da \qquad (1.5.14)$$

where b is the birth rate; p(a) is the probability of surviving to age a according to the prevailing life table at time t; c(a) is the proportion of the population that is aged a; m(a) is the rate of bearing female children for women aged a; and α and β are the lower and upper ages of child-bearing.

Preston and Coale (1982) manipulated these equations to develop a technique that obtains net reproduction rates from current p(a) and m(a) schedules. They also demonstrated the possibility of estimating the net reproduction rate (NRR) directly from a set of r(x)'s, the age-specific growth rates, and reported age distribution of mothers at child-birth. The proportion of births occuring to mothers aged a, v(a) at any time, t, can be estimated using information on births in the past year preceeding census.

$$\begin{aligned} NRR &= \int_{\alpha}^{\beta} p(a)\,m(a)\,da \\ &= \int_{\alpha}^{\beta} v(a)\,\exp\left(\int_0^{a} r(x)\,dx\right)da \qquad (1.5.15) \end{aligned}$$

Given NRR and p(m), the probability of surviving to the mean age of birth or the net maternity function, the gross reproduction rate (GRR) can be estimated. With the sex ratio at birth these can be used to estimate the total fertility rate (TFR), and with p(a)'s crude birth rates can be estimated.

Mwobobia (1982) attempted to estimate total fertility for Kenya using stable population models on the basis of (a) the cumulative age distribution, and (b) the 1969 and 1979 intercensal population growth rates. He abandoned the approach because "...the application of stable population models for estimation of total fertility rates (...) failed"[12] Some districts like Turkana and Marsabit, showed negative rates of growth; for some districts proportions under the various ages were found to be higher than those in any of the stable population models with the respective life expectancies; and in some cases where the correct proportions could be obtained from model stable populations, total fertility rates of more than ten were estimated. Inapplicability of stable population models was ascribed to inter-district migration.

Mwobobia's work (Mwobobia,1982) attributed population growth only to natural increase. However, besides natural increase population change due to migration is considerable. In the stable population model (where population change is attributed only to natural increase) the age distribution is expressed in (1.5.12). Migration included, it may be re-written:

$$c(a) = b\ p(a)\ [\exp(-\int_0^a [\ r(x)+e(x)]\ dx)] \qquad (1.5.16)$$

where

e(x) is the net out-migration rate.

Replacing c(a) and 'b' in 1.5.12 by N(a)/N and N(0)/N, respectively, it can be demonstrated that the out-migration rate between age "a" and "a+5" may be expressed:

$$ {}_5e_a = \frac{-1}{5} \ln\left[\frac{N(a+5)}{N(a)} * \frac{p(a)}{p(a+5)}\right] - {}_5r_a \qquad (1.5.17) $$

where

p(a) is the probability of survival to age "a",

${}_5r_a$ is the age-specific growth rate between "a" and "a+5"

and

N(a) is the number of persons aged "a" , a proportion of the total population, N.

This improved technique is not known to have been tried on Kenya's census data to estimate intercensal fertility levels. By relying only on the age structure of the population and life tables the age-specific growth rate technique will not only provide consistency checks for other methods of analysis, but will also be useful in interpreting and understanding the effect of migration on fertility levels.

1.6 SCOPE AND LIMITATIONS OF THE STUDY.

The discussions in later chapters shall reveal the scope and the limitations of the various methods of analysis. What is imediately available is the source of, and a preliminary view of the quality of data.

1.6.1 SOURCE OF DATA.

This study will draw information from the 1969 and 1979 censuses, provided by the Central Bureau of Statistics, Ministry of Plannig and National Development.

1.6.2 QUALITY OF DATA.

Over the 1969 and 1979 intercensal period considerable changes occured in demographic events but the quality of data did not change appreciably. No substantial improvement in the 1979 census data over the 1969 ones was observed. Both censuses produced poor data.(13)

Errors in the data were in the form of incomplete coverage and omissions,especially in Turkana District and North Eastern Province. Using Myer's and Whipple's Indices the data were observed to have inaccuracies in age reporting. It is also possible that age-related differences occured between the censuses in reporting fertility events, although under-enumeration was corrected for the 1979 census age-sex distribution by projecting the 1969 census fertility and mortality information.(14)

The impact of these on the estimated pattern and level of fertility is not known. In comparison of 1969 and 1979 censuses, however, the 1979 census reports noted that in the absence of changes in fertility - wich is unlikely - declines in mortality were not expected to affect the age structure significantly.

1.7 DEFINITION OF TERMS

BIRTH RATE (CRUDE BIRTH RATE):

A rate calculated by relating the number of live births observed in the Kenyan population during the 1969 to 1979 intercensal period to the size of the population during that period; or the number of births per thousand population.

AGE-SPECIFIC FERTILITY RATE:

The yearly number of live births per thousand women in each of the five-year age groups (15 -19 through 45 -49).

NET REPRODUCTION RATE:

The average number of daughters that a woman will bear if she experiences a given set of age-specific fertility rates throughout the reproductive ages with allowance made for mortality of women during their reproductive years.

GROSS REPRODUCTION RATE:

The average number of daughters a woman would have if she experiences a given set of age-specific fertility rates throughout her reproductive ages with no allowance for mortality over this period.

TOTAL FERTILITY RATE:

The number of children a woman would bear from age fifteen to age forty-nine if she were to bear children at the prevailing age-specific fertility rates.

MEAN AGE AT BIRTH:

The mean age of mothers giving birth to live daughters with current age-specific fertility and mortality rates. It is also known as the mean length of a female generation. This is the equivallent length of period over which the net reproduction rate measures the increase in a stable population implied by the given age-specific fertility and mortality rates.

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CHAPTER TWO.

INTERCENSAL FERTILITY ESTIMATIONS BASED ON THE P/F RATIO METHODS.

2.1 INTRODUCTION.

In this study a comparison of intercensal fertility estimates for Kenya between 1969 and 1979 is sought. The techniques under consideration are the Brass P/F Ratio method, the Coale-Trussell P/F Ratio method, Coale-Demeny's (1967) $P3^2/P2$ formula, Brass-Rachad (1979) $P2(P4/P3)^4$, the relational Gompertz model and the age-specific growth rate technique.

Two of these techniques namely the Brass P/F Ratio method and the Coale-Trussell P/F Ratio method are discussed in this chapter.

The P/F ratio methods are a means of adjusting the level of observed age-specific fertility rates. Estimation of an adjustment factor for period fertility on the basis of comparing cumulated period fertility rates, F(i), with lifetime average parities, P(i), is valid only if fertlity has been approximately constant in the fifteen years preceding the census (United Nations, Manual X, p.41). If fertility has been changing, the use of such an adjustment factor will tend to obscure effects of changes in fertility. This problem is avoided by constructing hypothetical intercensal average parities for a particular period (instead of a lifetime experience) and comparing them with cumulated average fertility rates for the same period.

What follows is a brief description of the additive synthetic technique.

2.2 THE ADDITIVE SYNTHETIC ADJUSTMENT TECHNIQUE.

The additive synthetic technique requires that two sets of data be either five years or ten years apart. Suppose P(i,1) is the average parity of the ith age group in the first census and P(i,2), in the second census. Suppose the synthetic average parity is denoted P(i,s) then

$$P(i,s) = P(1,2)$$

for the case of two censuses being five years apart, and

$$P(i,2) - P(i-1,1) + P(i-1,s) \qquad (2.1)$$

for i = 2 through 7.

Where the censuses are ten years apart

$$P(1,s) = P(1,2),$$

$$P(2,s) = P(2,2),$$

and

$$P(i,s) = P(2,i) - P(i-2,1) + P(i-2,s) \qquad (2.2)$$

for i = 3 through 7.

For the age-specific fertility rates the notations P(i,1), P(i,2) and P(i,s) were replaced by f(i,1), f(i,2) and f(i,s), respectively.

Since the data was obtained from the 1969 and 1979 censuses the adjusted average parities, P(i,s), and the age-specific fertility rates, f(i,s), were calculated using the ten-year synthetic approach.

Table 2.2.1 shows the raw data for the calculation of average parities and fertility rates: the female population

(FPOP), children ever born (CEB), and the number of births in twelve months preceding the 1979 census. For 1969 the average parities and the age-specific fertility rates were directly available from the 1969 census analytical reports.

Table 2.2.1: Average Parities and fertility rates for Synthetic Cohorts, Kenya.

AGE GROUP	Index i	FPOP 1979	CEB 1979	BIRTHS 1979	P(i,s)	f(i,s)
15-19	1	887722	284585	95638	0.320578	0.107734
20-24	2	686003	1272061	201211	1.854308	0.293309
25-29	3	541261	1976744	167023	3.622687	0.305115
30-34	4	412691	2223613	105123	5.36239	0.263634
35-39	5	325367	2105212	63486	6.442956	0.210536
40-44	6	273702	1921808	28442	7.273924	0.114549
45-49	7	221965	1592275	10577	7.616497	0.057787

Source: Kenya Population Census, 1979, vol. 2;and Kenya Population Census, 1969 Analytical Reports, Vol.IV.

2.3 THE COALE-TRUSSELL P/F RATIO METHOD.

Let f(i,s) be the age-specific fertility rate of women in the ith five year age group. The cumulated fertility schedule is:

$$Q(i,s) = 5 \sum_{j=1}^{i} f(j,s) \qquad (2.3.1)$$

The average parity equivallents are obtained by:

$$F(i,s) = Q(i-1,s) + a(i,s)f(i,s) + b(i,s)f(i+1,s) + c(i,s)Q(7,s)$$

for i = 1,2,3,4,5 and 6; and

$$F(7,s) = Q(6,s) + Q(7,s)f(6,s) + b(7,s)f(7,s). \qquad (2.3.2)$$

The values of the coefficients a(i,s), b(i,s) and c(i,s) are given in Table 2.3.3(a). These were estimated by applying the least-squares method to the data on the Coale-Trussell fertility model (Coale-Trussell,1974).

Table 2.3.3(a):Coefficients for Interpolation Between Cumulated Fertility Rates to the Estimated Parity Equivalents.

Age Group	Index (i,s)	a(i,s)	b(i,s)	c(i,s)
15-19	1	2.531	-0.188	0.0024
20-24	2	3.321	-0.754	0.0161
25-29	3	3.265	-0.627	0.0145
30-34	4	3.442	-0.563	0.0029
35-39	5	3.518	-0.763	0.0006
40-44	6	3.862	-2.481	-0.0001
45-49	7	0.392	2.608	

Source:United Nations, Manual X, 1983, p.34.

The age-specific fertility rates, f(i,s) refer to unorthodox age groups that, on average, are shifted by six months, since they are with respect to exact age rather than age at last birthday of mothers. A fertility schedule for conventional five-year age groups, $f^{+}(i,s)$, is estimated by weighting the f(i,s) rates:

$$f^{+}(i,s) = [1-w(i,s)f(i,s)+ w(i,s)f(i+1,s). \quad (2.3.3)$$

For every five-year age group, i, the weighting factor is calculated by:

$$w(i,s) = x(i,s)+ y(i,s)f(i,s)/Q(7,s)+ z(i,s)f(i+1,s)/Q(7,s) \quad (2.3.4)$$

The values of x(i,s), y(i,s) and z(i,s) are obtained by fitting the above equation by least-squares regression to the same model cases used in deriving the coeffients presented in Table 2.3.3(a). No weighting factor is required for i = 7, as child-bearing is assumed to cease after the age of fifty years. Thus

$$f^{+}(7,s) = [1-w(6,s)]f(7,s). \quad (2.3.5)$$

Table 2.3.3(b): Coefficients for Calculation of Weighting Factors to Estimate Age-specific fertility rates for Conventional Age Groups Shifted by Six Months.

Age Group	Index (i,s)	x(i,s)	y(i,s)	z(i,s)
15-19	1	0.031	2.287	0.114
20-24	2	0.068	0.999	-0.233
25-29	3	0.094	1.219	-0.977
30-34	4	0.12	1.139	-1.531
35-39	5	0.162	1.739	-3.592
40-44	6	0.27	3.454	-2.492
45-49	7	-	-	-

Source:United Nations, Manual X, 1983, p.34.

The P(i,s)/F(i,s) ratios are calculated from average parities and the estimated parity equivalents. The age-specific fertility rates are adjusted by a factor,k, obtained from the arithmetic mean of all P(i,s)/F(i,s) shown in Table 2.3.3(c). The technique is illustrated using data for Kenya at the national level.

Table 2.3.3(c): Calculation of Total Fertility Rate, Kenya.

AGE GROUP	Index (i,s)	Cur.Fert. f(i,s)	Cum.Fert. Q(i,s)	w/Factor w(i,s)	+ f (i,s)
15-19	1	0.107734	0.606612	0.073223	0.121322
20-24	2	0.293309	2.079147	0.101486	0.294507
25-29	3	0.305115	3.581647	0.111256	0.300499
30-34	4	0.263634	4.868842	0.116672	0.257438
35-39	5	0.210536	5.847056	0.155158	0.195642
40-44	6	0.114549	6.379415	0.142298	0.106471
45-49	7	0.057787	6.627235	-	0.049563

Index (i)	F(i,s)	P(i,s)	P(i,s)/ F(i,s)	* f (i,s)
1	0.267605	0.320578	1.197951	0.145983
2	1.464791	1.854308	1.265918	0.35437
3	2.994961	3.622686	1.209593	0.361581
4	4.376824	5.36239	1.225178	0.309767
5	5.479851	6.442954	1.175753	0.23541
6	6.134619	7.273924	1.185717	0.128113
7	6.550415	7.616494	1.162749	0.059638

Table 2.3.3(c) illustrates several stages in the adjustment of current fertility data, f(i,s), to correspond to information on average parities, P(i,s); and the use of the former after adjustment to estimate the total fertility rate. Age-specific fertility for Kenya is cumulated at each age group and denoted Q(i,s).that is:

$$Q(i,s) = 5[\sum_{j=1}^{i} f(j,s)]. \qquad (2.3.6)$$

So Q(7,s) = 6.627235. For the first age group, say, f(1,s) is weighted by the factor:

w(1,s) = .031 +2.287(.107734)/6.627235 +.114(.293309)/6.627235.

= 0.73223.

The fertility rate for the conventional 15 to 19 years age-group (that is not shifted) is estimated by:

$$f^{+}(1,s) = [1-w(1,s)]f(1,s) + w(1,s)f(2,s)$$

$$= [1-.73223(.107734) + .73223(.293309).$$

$$= 0.121322.$$

Cumulated fertility for the 15 to 19 age group is calculated by

$$F(1,s) = Q(1,s) + a(1,s)f(1,s) + b(1,s)f(2,s) + c(1,s)Q(7,s).$$

$$= .606612 + 2.531(.107734) + -0.188(.293309)$$

$$+ .0024(6.627235)$$

$$= .267605.$$

Computation for age groups 2 through 6 is executed in a simílar manner. Since child-bearing is assumed to cease after age 50 the conventional fertility rate for women aged 45 to 49 is not weighted, and its calculation is based on the weighting factor for the 40 to 44 years age group:

$$f^{+}(7,s) = [1-w(6,s)]f(7,s)$$

$$= [1-.142298](0.057787)$$

$$= .049563.$$

The cumulated fertility or the parity equivalent for the 45 to 49 years age group is also obtained differently:

$$F(7,s) = Q(6,s) + Q(7,s)f^{+}(6,s) + b(7,s)f^{+}(7,s)$$

$$= 6.379415 + 6.627235(.106471) + 2.608(.049563)$$

$$= 6.550415.$$

An adjusted fertility schedule is computed by:

$$f^{*}(i,s) = k\ f(i,s), \text{ where}$$

$$k = \{\sum_{i-1}^{7} [P(i,s)/F(i,s)]\}/7.$$

$$= [1.197951+1.265918+1.209593+1.225178+1.175753$$

$$+1.185717+1.162749]/7.$$

$$= 1.203266.$$

$$f^{*}(1,s) = 1.203266(.121322)$$

$$= 0.145983.$$

Total fertility rate for Kenya is thus obtained by

$$TFR = 5\sum_{i=1}^{7} f^{*}(i,s)$$

$$= 5[.145983+ .35437+ .361581+ .309767$$

$$+ .23541+ .128113+ .0596387]$$

$$= 7.974327.$$

In a similar manner as illustrated above for Kenya, at the national level, total fertility rates were calculated for provinces and districts. The total fertility rates are listed below.

Table 2.3.3(d):
TOTAL FERTILITY ESTIMATES BY COALE-TRUSSELL P/F RATIO METHOD.

REGION	1969	Intercensal	1979
KENYA	8.03	7.974	8.10
NAIROBI	5.81	4.137	4.86
CENTRAL	8.54	7.924	8.47
KIAMBU	8.72	5.699	8.16
KIRINYAGA	7.51	7.691	8.70
MURANGA	8.53	6.292	8.50
NYANDARUA	9.36	6.947	9.47
NYERI	8.62	6.019	8.16
COAST	6.20	7.617	7.10
KILIFI	6.67	8.952	7.36
KWALE	6.40	7.956	7.33
LAMU	4.87	9.704	7.32
MOMBASA	5.11	5.068	5.66
TAITA	7.01	8.6799	8.06
T.RIVER	6.24	9.861	8.13
NYANZA	8.71	7.765	8.61
KISII	10.37	9.028	10.03
SIAYA	7.85	6.993	7.83
S.NYANZA	8.45	7.747	8.50
KISUMU	8.05	7.592	8.10
WESTERN	9.11	6.626	8.96
KAKAMEGA	9.11	6.075	9.07

Table 2.3.3 (d) Continued:

REGION	1969	Intercensal	1979
BUNGOMA	9.48	7.843	9.42
BUSIA	8.63	7.234	8.07
N.EASTERN	8.10	5.272	6.99
GARISSA	8.63	-3.189	7.92
MANDERA	9.54	8.324	7.30
WAJIR	7.17	5.397	7.12
EASTERN	7.95	6.350	8.29
EMBU	8.50	6.796	8.93
ISIOLO	6.28	9.398	6.79
KITUI	7.64	5.547	8.10
MACHAKOS	7.92	6.656	8.58
MARSABIT	5.56	4.957	6.46
MERU	8.43	6.752	8.13
R.VALLEY	7.32	8.927	8.48
BARINGO	7.31	11.710	8.71
MARAKWET	7.27	7.503	7.69
LAIKIPIA	6.52	7.873	8.64
NAKURU	8.61	9.222	8.85
KERICHO	8.12	10.048	9.11
NANDI	7.03	9.016	8.57
NAROK	6.15	8.782	8.03
SAMBURU	6.84	8.882	6.97
T.NZOIA	8.07	5.739	9.32
KAJIADO	7.82	5.785	7.98
W.POKOT	6.80	10.563	8.29
TURKANA	4.81	11.659	6.72
U.GISHU	7.98	8.753	8.66

The level of total fertility rates obtained by the Coale-Trussell P/F ratio method depended on the multiplying factor, k. Originally the ratios F2/F2 or F3/F3 were considered to adjust age-specific fertility rates most accurately. However, in this study, for almost all districts P(i)/F(i) ratios for younger age groups are rather high. Since they seem reasonably consistent,albeit higher than the anticipated unity, for all age groups age-specific fertility rates were adjusted by a factor obtained by the arithmetic mean of all P(i)/F(i).

Fertility schedules obtained by such an adjustment factor seem to provide reasonable estimates of total fertility. A few districts within the Rift Valley like Turkana, Baringo and West Pokot seemed to have rather high total fertility rates. This could possibly be attributable to the quality of data as is clearly demonstrated in the case in Garissa District with a total fertility rate of -3.2 children per woman. Intercensal estimates for Rift Valley may well have been affected by differential coverage between the censuses. (Mwobobia,1982).

Comparison of intercensal total fertility rates with those obtained for 1969 and 1979 censuses separately shows an interesting inconsistency. Of all the provinces and districts, only Kirinyaga's intercensal values lie between the two censuses'. In most cases the intercensal rates are by far above or below either censuses',suggesting either over-adjustment by the additive synthetic adjustment technique or distortion caused by differential coverage between the censuses. Generally, where fertility levels seem to have risen from 1969 to 1979 the intercensal levels are higher than the latter census. The reverse is true where fertility seems to have fallen from 1969 to 1979.

2.4: THE BRASS P/F RATIO METHOD.

2.4.1 Introduction.

The Brass P/F Ratio method operates on the same principles as the Coale-Trussell P/F Ratio Method in 2.3. Total fertility rate is estimated on the basis of comparing cumulated period fertility rates, F(i), with lifetime fertility or average parities, P(i). There is, again, need to employ multiplying factors which are interpolated in order to convert F(i) values to correspond to P(i) values.

2.4.2 The Method.

Suppose f(1,s) and f(2,s) are the age-specific fertility rates for hypothetical cohorts of women aged 15 to 19 years and 20 to 24 years, respectively. The ratio f(1,s)/f(2,s) is used for every cohort to estimate a multiplying factor, k(i,s) by interpolating from values listed in Table 2.4.2(a). The method is illustrated using Kenya data at national level.

Table 2.4.2(a)
Multiplying Factors k(i,s) for Estimating Average Value of F(i,s).

AGE GROUP	Multiplying Factors k(i) for Values of f(i,s)/f(2,s).					
1	1.12	1.31	1.615	1.95	2.305	2.64
2	2.555	2.69	2.78	2.84	2.89	2.925
3	2.925	2.96	2.985	3.01	3.035	3.055
4	3.055	3.075	3.095	3.12	3.14	3.165
5	3.165	3.19	3.215	3.245	3.285	3.325
6	3.325	3.375	3.435	3.51	3.61	3.74
7	3.64	3.895	4.15	4.395	4.63	4.84
f(1)/f(2)	0.036	0.113	0.213	0.33	0.46	0.605

Source: Brass, 1975, p.22; Adapted from U.N. Department of Economic and Social Affairs, 1967, p. 124.

For example k(1,s),the multiplying factor for the cohort of women aged 15 to 19 is interpolated thus: The ratio f(1,s)/f(2,s) obtained from census data is 3.67305. This falls between two ideal United-Nations-provided values 0.33 and 0.46 in the table above. Their corresponding values of k(i) are 1.95 and 2.305, respectively. So the multiplying factor for the hypothetical cohort aged 15 to 19 years is obtained by:

$$k(1,s) = 1.95 + (2.305-1.95)*(.367305-0.33)/(0.46-0.33)$$
$$= 2.051872.$$

For subsequent age-groups (20 to 24 through 45 to 49) the multiplying factors, k(i,s) are interpolated in a similar manner and listed in Table 2.4.2(b).

Table 2.4.2(b):
Calculating total fertility rate, Kenya.

AGE GROUP	Cur.Fert. f(i,s)	Factors k(i,s)	Cum.Fert. F(i,s)	P(i,s)	P(i,s)/ F(i,s)	* f (i,s)
15-19	0.107734	1.048846	0.112996	0.320578	2.837064	0.134148
20-24	0.293309	2.713076	1.334439	1.854308	1.389577	0.365222
25-29	0.305115	2.946538	2.904248	3.622686	1.247374	0.379923
30-34	0.263634	3.069230	4.339943	5.36239	1.235589	0.328272
35-39	0.210536	3.143461	5.510771	6.442954	1.169156	0.262155
40-44	0.114549	3.256153	6.274629	7.273924	1.159259	0.142634
45-49	0.057787	3.798461	6.693886	7.616494	1.137828	0.071955

The factors adjust the cumulated current fertility rates for the hypothetical intercensal cohorts, F(i,s).

$$F(i,s) = 5\sum_{j=1}^{i-1} f(j,s) + k(i,s)f(i,s) \qquad (2.4.1)$$

for i,j = 1 through 7.

The ratio of average parities, P(i,s) to the parity equivallents, F(i,s) is used to adjust the level of recent fertility. The arithmetic mean of all P(i,s)/F(i,s) is selected as an adjustment factor. This is considered more accurate than the use of P(2,s)/F(2,s) that was originally proposed by Brass (Brass,1975) but is,here, very high.

$$K(i,s) = [1.450208+1.347728+1.38186+1.231362+1.164129 +1.153310+1.131343]/7.$$

$$= 1.245181.$$

The adjusted current fertility schedule is thus obtained by:

$$f^*(i,s) = 1.245181 f(i,s). \quad (2.4.2)$$

The total fertiltiy rate for Kenya is obtained by:

$$TFR = 5\sum_{i=1}^{7} f^*(i,s) \quad (2.4.2)$$

$$= 8.421561.$$

The above exemplifies the procedure used to estimate total fertility rates listed below for provinces and districts.

Table 2.4.3(c):
TOTAL FERTILITY RATES OBTAINED BY THE BRASS P/F RATIO METHOD.

REGION	Anker 1969	Inter-censal	Mwobobia 1979
KENYA	-	8.04	8.52
NAIROBI	5.74	4.34	5.39
CENTRAL	-	6.75	-
KIAMBU	8.64	5.95	8.59
KIRINYAGA	7.66	8.23	9.30
MURANGA	8.14	6.89	9.05
NYANDARUA	8.69	7.42	9.95
NYERI	8.32	6.52	8.82
COAST	-	7.84	-
KILIFI	6.43	9.09	8.02
KWALE	6.20	8.10	7.71
LAMU	4.51	9.70	7.58
MOMBASA	4.86	5.07	5.64
TAITA	6.98	8.68	8.39
T.RIVER	6.49	9.86	8.58
NYANZA	-	8.11	-
KISII	10.42	9.64	10.10
SIAYA	7.63	7.73	8.02
S.NYANZA	8.54	7.34	7.35
KISUMU	8.32	8.06	7.69

Table 2.4.3(c) Continued...

EASTERN	-	6.91	-
EMBU	8.09	7.47	9.82
ISIOLO	6.56	9.45	7.13
KITUI	7.07	5.14	8.92
MACHAKOS	7.76	7.29	9.23
MARSABIT	5.87	5.53	7.28
MERU	7.86	7.27	8.54
N.EASTERN	-	4.60	-
GARISSA	8.02	-1.47	8.63
MANDERA	8.30	8.32	7.79
WAJIR	7.98	5.87	7.60
WESTERN	-	8.05	-
KAKAMEGA	9.42	7.58	9.09
BUNGOMA	9.71	8.87	9.65
BUSIA	8.65	7.33	8.14
R.VALLEY	-	9.19	-
BARINGO	7.23	8.10	9.33
MARAKWET	7.08	4.59	8.40
LAIKIPIA	6.45	6.87	9.40
NAKURU	7.91	6.73	9.10
KERICHO	8.50	8.63	9.37
NANDI	6.73	8.62	9.10
NAROK	6.31	7.84	8.41
SAMBURU	5.72	7.45	7.21
T.NZOIA	7.76	7.35	9.62
KAJIADO	6.89	6.87	8.58
W.POKOT	6.70	7.63	7.70
TURKANA	4.74	6.79	5.67
U.GISHU	7.36	7.54	9.41

Sources: Mwobobia,I.K. 1982. Fertility Differentials in Kenya: A Cross-regional Study. M.A. Dissertation. Population Studies and Research Institute. Nairobi. p.78.
Anker,R.and Knowles,T. 1982. Fertility Determinants in Developing countries: A Case Study of Kenya. I.L.O. Liege. p.8.

2.4.4 COMPARISON OF TOTAL FERTILITY ESTIMATES OBTAINED BY BRASS P/F RATIO METHOD.

Intercensal total fertility estimates obtained by the Brass P/F ratio method seem to be consistent with fertility levels estimated by other researchers for the 1969 and 1979 individual censuses (Table 2.4.3(c)). Also the intercensal estimates vary from the separate censuses by smaller deviations than in the case of the Coale-Trussell P/F ratio method. They, however still do not necessarily fall between the 1969 and 1979 estimates.

Both Anker and Knowles (1982) and Mwobobia (1982), in deriving their estimates, experienced the common problem high P(i)/F(i) ratios for younger women. They had to find more agreable ratios to adjust the levels of current fertility. Whereas Anker and Knowles used the ratio

$$[P(4)/F(4)+P(5)/F(5)]/2 \qquad (2.4.4)$$

Mwobobia used

$$[P(2)/F(2)+P(3)/F(3)]/2. \qquad (2.4.5)$$

The P/F ratio methods generally assume that if the adjustment factor is got from data on younger women, omission of children ever born by older women does not affect results.

But in this exercise, in common with othe researchers, it appears that this salient assumption has to be overlooked. Better results are obtained by employing P/F ratios of older women, or using an average of a wider spectrum of ages.

In this study adjustment factors are obtained by averaging all P(i,s)/F(i,s). The merit of this choice of adjustment factors is that hypothetical cohort parities and age-specific fertility rates are obtained by differencing 1969 and 1979 values; The use of all P(i,s)/F(i,s) downplays the truncation effect in younger age groups caused by the use of the additive synthetic technique and includes as many values adjusted by differencing as possible. (This is not the principal reason for selecting the arithmetic mean of all P(i,s)/F(i,s): These were found to be high and inconsistent for the younger age groups).

If there is agreement between cumulative fertility,F, and parity,P, measurements, the ratio should be close to unity. The ratios P(i,s)/F(i,s) are far from being close to unity in the whole republic except for Isiolo District.

Were the ratios for the younger age groups closer to unity they would indicate that the data on births in the year preceeding census were consistent with the data given by the same women regarding the number of children ever born.One must assume inconsistency between the two sets of data. The ratios P(1,s)/F(1,s) range from 1.028 (Kiambu district, Coale-Trussell) to an alarming 1.954 (West Pokot,Brass). Most of

Table 2.4.4(a):
P/F Ratios and Adjusted Fertility Schedules For Isiolo District

Coale-Trussell Method			Brass Method	
Age Group	P(i)/F(i)	* f (i)	P(i)/F(i)	* f (i)
15-19	1.046136	0.107379	1.303614	0.10147
20-24	1.137058	0.277907	1.244033	0.290078
25-29	1.039597	0.288419	1.069651	0.299203
30-34	1.002676	0.308887	1.008504	0.326611
35-39	0.885256	0.284561	0.871583	0.297205
40-44	0.816008	0.296663	0.748471	0.303596
45-49	0.696194	0.315688	0.686765	0.271582

ratios lie between 1.3 and 1.6. Garissa District seems an obvious case of gross error in the data with P/F ratios of over 2.00 for P(1,s)/F(1,s) and less than -6.00 for P(7,s)/F(7,s). On the average, at the national level, the ratio are rather high.

Table 2.4.4(b):
P/F Ratios and Adjusted Fertility Schedules For KENYA.

Age Group	Coale-Trussell Method a.s.f.r. f(i)	P(i)/F(i)	f* (i)	Brass Method P(i)/F(i)	f* (i)
15-19	0.107734	1.197951	0.145983	1.450208	0.134148
20-24	0.293309	1.265918	0.35437	1.347728	0.365222
25-29	0.305115	1.209593	0.361581	1.238186	0.379923
30-34	0.263634	1.225178	0.309767	1.231362	0.328272
35-39	0.210536	1.175753	0.23541	1.164129	0.262155
40-44	0.114549	1.185717	0.128113	1.15331	0.142634
45-49	0.057787	1.162749	0.059638	1.131343	0.071955
		k = 1.203266		k = 1.245181	

Disagreement of 'P' and 'F' measurements could emanate from reference period errors that afflict data on births twelve months before census, although these were adjusted for in both the techniques. It is logical to assume P(1), P(2) or P(3) as being correct since they refer to recent events and did not require sophisticated adjustment besides the synthetic adjustment technique. At the national level the ratios decline with age as expected in situations where older women under-report the number of children ever born. This aggregate trend is however not representative. P/F ratios decline with age in a few districts in Rift Valley Province and Coast Province. In most districts the ratios do on the contrary rise with age,and even more steeply for women aged above forty.

When P/F Ratio methods are applied in cases of declining fertility P(i)/F(i) ratios have a tendency to rise with age. This is not automatically admissible as evidence of declining fertility in those districts: the use of average parities for a hypothetical intercensal cohort eliminates this rising trend of ratios with age (Zlotnik & Hill,1981,p.110).

Relative levels of total fertility obtained by the P/F Ratio methods seem to conform to what is known of fertility in Kenya. For example more urbanised districts have relatively low fertlility. High potential agricultural areas have high fertility rates. However, in North Eastern Province and some Rift Valley districts - Turkana and Samburu - seem to have higher levels than one would expect.

2.5 Conclusion.

Total fertility rates obtained by the Coale-Trussell method are slightly lower than those calculated by the Brass technique. Their P(i,s)/F(i,s) ratios were more or less similar. Notably, P(1,s)/F(1,s) values were much higher for the technique. This may have emanated from the use of different indices from real but different populations in choosing the appropriate models.

The techniques seem to give reasonable estimates. The merit of P/F Ratio techniques is that they are based on information arrived at internally (Brass, 1975, p.16). Unfortunately the only way of judging the success of these techniques is to view estimates and see if they are reasonable and seem to agree with what is generally known of the country. Fertility levels that have been estimated for the intercensal period are consistent with those in previous works. Occasional deviations, especially exemplified by the Coale-Trussell method are difficult to ascribe to any particular error for lack of proof.

Failure of P/F methods may be explained by inadequacy in basic data, or in the additive adjustment technique. To a good measure the methods seem to be sensitive to errors in data or in coverage like in the case of Garissa District, Kericho, Turkana, Baringo and West Pokot. It is possible that differential coverage between the two censuses is a major factor in the performance of the methods using the additive synthetic technique.

CHAPTER THREE.

INTERCENSAL FERTILITY ESTIMATION BASED ON REPORTED LIFETIME FERTILITY.

3.1 Introduction.

The analysis of P/F Ratio methods suggested disparities between current fertility data and information on children ever born reported by the same women. The two procedures examined in this chapter, namely Coale-Demeny's $P3^2/P2$, and Brass-Rachad's $P2(p4/P3)^4$ formulae will further assist in highlighting the nature of errors that may afflict Kenya's census data. But mainly they will be employed in estimation of total fertility rates for comparison with those obtained by the P/F Ratio methods. The procedures are relatively simple and rely only on lifetime fertility data which is likely to be reported more accurately. They estimate total fertility from the average parities of younger women and compare it with the average parities of women aged over forty-five years.

3.2 COALE-DEMENY'S $P3^2/P2$ PROCEDURE.

Average parities for cohorts of women in age-groups 20 to 24 years and 25 to 29 years are refered to as P(2,s) and P(3,s), respectively. The ratio TF/P(3,s) closely approximates P(3,s)/P(2,s). (U.N., Manual IV, 1967). Total fertility is approximated by

$$TFR = P(3,s)^2/P(2,s) \qquad (3.1.1)$$

The basis of this is that where birth control is not widely practised (and rise and fall of fertility with age is strongly affected by customs and institutions governing marriage or establishment of sexual unions) the shape of the early part of the fertility schedule is dominated by the age pattern of entry into regular sexual unions rather than the age schedule of fecundability (U.N.,Manual IV). Also decline in fertility with age is governed more by declining fecundability than by customs and institutions. Thus fertility decline with age follows a roughly similar pattern in various populations while age of entry into cohabitation has no such similarity.

These suggest that the ratio of the average parity of a younger, say 25 to 29 years age group, is closely related to relative parity of women in their early and late twenties. Hence $(P3,s)^2 /P(2,s)$ is thought to be appropriate for Kenya, as it provides a method of estimating total fertility when older women are likely to under-report the number of children ever borne and the younger to report parity accurately.

3.3 BRASS-RACHAD'S $P2(P4/P3)^4$ PROCEDURE.

Basing on similar reasoning, a wider range of average parities of younger women may be used to estimate total fertility. If average parity for a hypothetical cohort of women aged 30 to 34 years is denoted P(4,s), total fertility may, alternatively be determined by

$$TFR = P(2,s)[P(4,s)/P(3,s)]^4. \qquad (3.2.1)$$

Total fertility rates were estimated for Kenya, at the national provincial and district levels using both the procedures. These rates are compared in Table 3.3.1. Estimates obtained by the first procedure are prefered (See section 3.4).

3.4: COMPARISON OF TOTAL FERTILITY ESTIMATES.

Total fertility rates calculated from the 1979 census provisional data using $(P3)^2/P2$ (Mwobobia,1982) were rather low. They were consistently lower than those obtained from the final 1979 census figures except for a few districts, namely Taita, Isiolo, Marsabit, and Samburu; and Kitui for which similar estimates were obtained. In the later case no extremely low estimates have been observed. In the former case, for example, Turkana District had a total fertility rate of 1.70 children per woman - as compared to 5.13 children in the later case.

Total fertility estimates calculated separately for the two censuses were compared. The 1979 total fertility estimates are not consistently higher or lower than those obtained from 1969 census. Cases of equality in total fertility rates between the two censuses are rare: These are confined to Kenya, at the national level and Kisii District.

A comparison of 1969 and 1979 total fertility estimates reveals interesting intra-province similarities. All districts in Central province have higher 1979 total fertility rates than 1969 ones. A similar trend is observable in Coast province, with the exception of Kilifi District, suggesting an increase in fertility levels. In Eastern Province Kitui, Machakos and Meru have higher 1979 total fertility rates, while at provincial level, Isiolo and Marsabit have lower 1979 total fertility rates. The largest decline is observed in Marsabit from 5.96 to 5.15 children per woman. North Eastern Province also exhibits a decline at provincial and district levels except for Garissa District. Wajir District had the largest decline from 8.17 to 6.97 children per woman. Nyanza Province had higher total fertility estimates for 1969 than 1979 census, with the exception of Kisii where both censuses had 9.05 children per woman. Extreme decline in total fertility rates was observed in Western Province where at both provincial and district levels there was a drop of more than one child per woman from 1969 to 1979. For example Bungoma District had total fertility rates of 9.19 and 7.91 children per woman in 1969 and 1979, respectively. This was exceeded only by Elgeyo Marakwet District in Rift Valley which exhibited a drop from 12.4 children per woman in 1969 to 7.3, in 1979. Generally, some Rift Valley districts showed an increase while some showed a decrease in total fertility levels between 1969 and 1979.

Inter-censal total fertility rates obtained from 1969-1979 synthetic data for most districts lie between fertility levels obtained for the two censuses separately. This moderating effect of the additive synthetic adjustment technique is especially observable in Central Province, Coast Province, and most of North Eastern and Nyanza provinces.

The synthetic total fertility rate for Kenya and the total fertility rates from the 1969 and 1979 censuses lie at about the same level. Nyanza Province, Embu and Bungoma districts have synthetic total fertility rates that are similar to the 1979 census levels.

Rift Valley Province has the most spurious trend in the relative level of synthetic total fertility rates. For some of its districts synthetic rates are higher than both the censuses', while in some cases they have the lowest levels. Baringo, Nandi and West Pokot districts' total fertility rates lie bewteen the 1969 and 1979 levels.

The general trend for the whole country is that those districts that showed an increase in fertility levels from 1969 to 1979 have synthetic total fertility rates either lying between 1969 and 1979 levels or higher than 1979 levels. The reverse seems to be the case where fertility levels seemed to decline from 1969 to 1979 levels: in such cases synthetic total fertility rates are even lower than the 1979 levels.

A similar trend is true for the Brass-Rachad procedure which is, however, suspect.

Table 3.4.1: TFRs CALCULATED BY THE $P3^2/P2$ AND $P2(P4/P3)^4$ PROCEDURES.

REGION	1969	1979	Intercensal p3 /p2	Intercensal P2(P4/P3)	Mwobobia
KENYA	7.086	7.193	7.078	8.902	5.96
NAIROBI	6.160	5.769	5.630	4.947	4.40
CENTRAL	7.199	8.225	7.774	8.347	-
KIAMBU	7.256	7.627	7.409	8.691	6.26
KIRINYAGA	6.926	8.452	8.003	8.483	6.45
MURANGA	7.451	8.049	7.820	7.928	6.90
NYANDARUA	6.741	8.879	8.464	8.953	7.70
NYERI	7.621	8.119	7.864	7.906	6.30
COAST	5.061	6.324	6.073	8.904	-
KILIFI	4.896	4.256	6.405	9.907	5.31
KWALE	5.161	6.681	6.428	8.743	4.84
LAMU	4.617	7.003	6.051	10.751	5.36
MOMBASA	5.163	5.322	5.080	5.466	4.18
TAITA	5.496	7.515	7.419	9.288	5.77
T.RIVER	5.061	6.786	6.209	11.904	5.34
NYANZA	7.965	7.683	7.683	9.803	-
KISII	9.049	9.051	9.417	10.479	6.37
SIAYA	7.149	6.864	6.885	9.419	5.64
S.NYANZA	7.721	7.217	7.262	9.707	5.31
KISUMU	7.747	6.759	6.733	8.838	5.65
WESTERN	8.685	7.629	7.499	10.088	-
KAKAMEGA	8.724	7.727	7.489	9.804	6.44
BUNGOMA	9.165	7.961	7.957	10.186	7.43
BUSIA	7.892	6.869	7.031	10.547	6.05
N.EASTERN	6.829	6.809	6.977	7.098	-
GARISSA	6.407	6.859	6.948	8.418	4.15
MANDERA	6.658	6.317	6.461	6.646	4.56
WAJIR	8.176	6.972	7.201	6.379	3.78
EASTERN	6.805	7.427	7.167	8.878	-
EMBU	8.002	7.781	7.781	8.589	6.87
ISIOLO	5.854	5.740	5.695	7.930	5.99
KITUI	6.967	7.385	7.237	9.967	6.38
MACHAKOS	6.726	7.825	7.32	10.167	6.38
MARSABIT	5.966	5.156	4.995	5.175	5.71
MERU	6.649	7.132	7.185	7.493	5.73
R.VALLEY	6.859	7.034	6.959	8.327	-
BARINGO	6.657	7.953	7.393	10.006	6.12
MARAKWET	8.062	7.313	6.827	3.190	5.22
LAIKIPIA	8.174	7.561	6.914	9.310	7.12
NAKURU	7.459	7.246	4.614	8.546	6.73
KERICHO	8.184	7.419	7.532	11.519	6.90
NANDI	6.637	7.228	7.097	10.223	6.75
NAROK	4.788	6.482	6.713	7.665	6.31
SAMBURU	4.736	5.937	6.104	6.915	6.61
T.NZOIA	7.897	7.326	6.927	7.151	7.03
KAJIADO	5.316	6.469	6.746	8.326	6.32
W.POKOT	5.573	6.897	6.473	9.163	5.17
TURKANA	4.566	5.129	5.506	7.874	1.70
U.GISHU	7.761	7.291	7.171	8.944	6.50

3.5 THE PERFORMANCE PROCEDURES THAT RELY ON LIFETIME FERTILITY DATA ONLY.

The Coale-Demeny procedure drew data from a very small age range as a basis for extrapolation to all reproductive years. The Brass-Rachad procedure used a wider range of ages. Brass(1975) observed that a small error in observed information or in the adjustment over the used age range often produced large deviations in the final estimates. In that respect the use of a wider age range in the latter technique seems to amplify errors in the basic data. Table 3.4.1 shows fertility rates estimated by the procedure to be very high. It may be logical to conclude that the Coale-Demeny's procedure is less affected by reporting errors since it uses more reliable average parities. On the contrary, the Brass-Rachad procedure would seem less sucessful because of its inclusion of older women whose reporting of information may not be as accurate.

Rachad (Brass and Rachad,1979) considered the lower of the estimates obtained by either procedure to be more accurate. Still, the Coale-Demeny procedure has, in all cases, lower estimates. It also seems to have a sound demographic basis that is relevant to Kenya's communities.

The use of this technique required that (a) the age pattern of declining fecundability was typical, and that (b) widowhood, divorce and other forms of dissolution of sexual unions did not have an unusual age incidence from age thirty to forty (U.N.,Manual IV, 1967). If "NATURAL" describes fertility in populations which exhibit no deliberate control of births (Henry,1961), Kenya's fertility pattern could reasonably be considered close to a typical, "natural" pattern. Both the 1977/78 Kenya Fertility Survey (KFS) and the 1984 Kenya Contraceptive Prevalence Survey (KCPS) revealed low contraceptive use in Kenya. Although knowledge of contraception at over 80%, was quite widespread, ever-use of contraception was 29% for both KFS and KCPS. The proportion of current users was 7% and 17% in 1979 and 1984, respectively among married women. Early and nearly universal marriages which remained stable were characteristics cited to be responsible for high cumulative fertility rates.

Whereas the procedure may be robust, the effect of reporting errors by older women could be considerable. The two procedures provide crude internal tests for omission of children ever born. Total fertility rates are compared with average parities of women aged over forty-five years.

Under circumstanses of a likelihood of under-reporting of children ever born by older women, if $P(3,s)^2/P(2,s)$ is substantially less than P(7,s) then data on children ever born may not be used to determine the level of fertility. If $P(3,s)^2/P(2,s)$ exceed P(7,s) then the estimates obtained by the formula gain credibility,although a substantial difference would indicate under-reporting by older women.(Brass,1975; Hill,1980). Such indicators of omission, albeit crude, are manifest in Muranga, Nyeri, Kisii, Wajir, Embu and Meru districts. The greatest incidence of omission is observable in Wajir District wher total fertility exceeds P(7,s) by 0.831 children.

In this case $P(3,s)^2/P(2,s)$ was found to be acceptable as an estimate of total fertility since for all districts it is approximately equal to P(7,s). For some districts P(7,s) exceed $P(3,s)^2/P(2,s)$ while for others the reverse is true, but there is no substantial difference.

If P(7,s) is taken to approximate total fertity, TF, comparison reveals a close proximity of the ratios TF/P(3,s) and P(3,s)/P(2,s). The Brass-Rachad procedure, however, showed less consistency in parity data; when the ratio TF/P(2,s) was compared to $(P(4,s)/P(3,s))^4$, wider differences were evident. But such a crude test may not be conclusive.

Table 3.5.1: Comparison of Parity Information for Hypothetical Cohorts At Provincial Level.

	Coale-Demeny			Brass-Rachad		
PROVINCE	TF/P3	P3/P2	Diff.	TF/P2	$(P4/P2)^4$	Diff.
Kenya	2.1	1.93	0.17	4.107	4.8	0.693
Nairobi	1.68	2.06	0.38	3.472	3.733	0.261
Central	2.19	2.16	0.03	4.525	4.842	0.317
Coast	2.07	1.77	0.3	3.67	4.515	0.845
Eastern	2.09	2.04	0.05	4.341	5.146	0.805
N.Eastern	2.27	2.22	0.05	5.035	4.993	0.042
Nyanza	1.93	1.91	0.02	3.696	4.592	0.896
Western	2.08	1.96	0.12	4.061	5.142	1.081
R.Valley	2.15	1.87	0.28	4.014	4.743	0.729

3.6 CONCLUSION.

The formula proposed by Brass,

$$TFR = P2(P4/P3)^4,$$

has consistently higher total fertility estimates than the Coale-Demeny one. The latter is therefore assumed to be more accurate (Brass and Rachad, 1979).

The procedure, using only information on mean parities for women in their twenties, generates acceptable estimates of total fertility. These rates are, for most districts, lower than those obtained by the P/F Ratio methods discussed in Chapter Two. When total fertility was approximated by P(7,s), the mean parity of women aged 44 to 49, the ratio TF/P(3,s) was found to be approximate to P(3,s)/P(2,s) - suggesting consistency in parity data. The procedure was was proven credible as [P(3,s)/P(2,s)] obtained total fertility rates that are close P(7,s).

It does not reveal much in terms of the types of error that the data may suffer. But one interesting trend is that the ratio P(7,s)/P(3,s) is consistently higher than P(3,s)/P(2,s) albeit by small margins (Table 3.5.1). This would mean that either P(7,s) values are over-estimated or P(2,s), under-estimated. The former is more plausible, implying that older women over-report the number of children ever born. Cases of women reporting grand-children as their own are not uncommon. (Anker, 1979, p.32). Another implied error would be exaggeration of age by older women, which inflates P(7,s). Analysis of the 1979 census cited such a problem, but this was less pronounced for women. These observations, based on less sophisticated tests, seem to contradict the view that older women under report children ever born. They are consistent with those infered from the behavior of P(i,s)/F(i,s) in Chapter Two. For most districts P(i,s)/F(i,s) ratios did not decline with age as expected in situations where older women under report lifetime fertility.

CHAPTER FOUR

INTERCENSAL FERTILTIY ESTIMATION USING THE GOMPERTZ RELATIONAL MODEL.

4.1: Introduction.

Reliance on only average parity information to estimate total fertility was successful. An important aspect that was left out alongside the relatively less accurate f(i,s) data was the true pattern of fertility. The P/F ratio methods in Chapter Two estimated the pattern of fertility from current births and fitted these to the mean parities for all women.

The relational Gompertz model discussed in this chapter is a modification of the P/F ratio methods, with some merits. The model does not neccessarily assume that the quality of reporting does not vary with the age of the respondent, or that fertility levels have been constant in the recent past.(Zaba, 1981, p.1).

The model was designed for evaluation and adjustment of fertility estimates obtained from retrospective data. A mathematical function is used to express the model linearly in terms of the unknown parameters - which simplifies comparison of models with actual observations. Measures used by the model are calculated from standard values that are linearly related to different populations.

The relational Gompertz model should be useful in detecting types of error present in fertility data with respect to the true trend of fertility levels.

4.2: The Model.

The model is represented by

$$F(x) = T \exp(-\exp(-(a+bYsx))), \qquad (4.2.1)$$

where F(x) is the cumulated fertility up to age x; and T is the total fertility rate. a and b are unknown parameters determined by the relation

$$a+bYs(x) = -\ln(-\ln(F(x)/T)) \qquad (4.2.2)$$

where Ys(x) = -ln(-ln Fs(x), and Fs(x) is the standard cumulated fertility to age x, with T = 1.0.

Similarly,

$$P(i) = T \exp(-\exp(-a+bYs(i))), \qquad (4.2.3)$$

where P(i) is the average parity for the ith five-year group.

Total fertility can be found directly from data if a and b are estimated by relating cumulated fertility, F(x), and average parity, P(i). That is: -ln(-ln F(x)/T) and -ln(-ln P(i)/T), and the corresponding Ys(x) and Ys(i) values, respectively.

Accurate estimation of T (Total fertility) is often difficult with retrospective data from developing countries. However, T can be estimated indirectly by relating the ratios of successive F(x) values and P(i) values, and parameters a and b. Zaba's procedure (Zaba,1981) separates the examination of fertility pattern from the examination of fertility level.

$$\text{If } z(x) = -\ln(-\ln \frac{F(x)}{F(x+5)}), \text{ or} \qquad (4.2.4)$$

$$z(x) = -\ln(-\ln \frac{T \exp(-\exp(-(a+bYs(x))))}{T \exp(-\exp(-(a+bYs(x+5))))}), \text{ and}$$

$$Qx(b) = -\ln[\exp(-bYs(x)) - \exp(-bYs(x+5))], \quad (4.2.5)$$

the term Qx(b) can be expanded by Taylor's approximation and substituted into z(x). It can then be shown that

$$z(x)-e(x) = a + bg(x) - (b-1)^2/2!Q''x(1) + \ldots \quad (4.2.6)$$

where

$$e(x) = Q'x(1)-Qx(1), \quad (4.2.7)$$

and

$$g(x) = -Q''x(1) \quad (4.2.8)$$

It is also demonstrable that:

$$z(x)-e(x) = a + bg(x) -((b-1)^2/2)c, \quad (4.2.9)$$

where c is a constant approximated by Q"x(1) for $15 < x < 35$.

That is z(x)-e(x) and g(x) are linearly related, having the slope b and intercept $a-c(b-1)^2/2$.

This relationship can be extended directly to average parities:

$$z(i) = -\ln(-\ln \frac{P(i)}{P(i+1)}). \quad (4.2.10)$$

and

$$z(i)-e(i) = a-((b-1)^2/2)c) + bg(i). \quad (4.2.11)$$

Total fertility, T, is estimated from reliable F(x) and P(i) values as follows:

$$T(x) = \frac{F(x)}{\exp(-\exp(-(a+bYs(x))))}, \quad (4.2.12)$$

or

$$T(i) = \frac{P(i)}{\exp(-\exp(-(a+bYs(i))))}. \quad (4.2.13)$$

4.3: Computational Procedure.

Values for P(i) and F(x) are derived for intercensal synthetic cohorts using the additive synthetic technique. For example, P(i) here actually refers to P(i,s). Similarly f(i) values are obtained for synthetic cohorts in the manner described in Chapter Two.

The cumulated fertility schedule, F(x) = Qi = Q(i), where

$$F(x) = Qi = Q(i), \qquad (4.3.1)$$

where

$$Q(i) = 5\sum_{j=1}^{i} f(j,s).$$

Step 1: P(i)/P(i+1) and F(x)/F(x+5) are first calculated.

Step 2: $z(i) = -\ln(-\ln(P(i)/P(i+1))$ and

$z(x) = -\ln(-\ln(F(x)/F(x+5)))$.

Step 3: For z(i)-e(i) and z(x)-e(x), e(i) values are tabulated in Table 4.3(b) while e(x) values are obtained from Table 4.3(a). It can also be estimated by:

Step 4: Estimation of a and b.

$$z(x)-e(x) = a + bg(x) - ((b-1)^2/2)c \text{ and}$$

$$z(i)-e(i) = a + bg(i) - ((b-1)^2/2)c.$$

a and b are estimated by using the least- squares method on the values of z(x)-e(x) and g(x); and on the values of z(i)-e(i) and g(i). That is: z(x)-e(x), say, are the y-values while g(x) constituted the x-values. g(x) and g(i) values are represented in Tables 4.3(a) and 4.3(b), respectively.

Table 4.3(a): Standard values for cumulated fertilities and their ratios with half year shifts.

Age x	Fs(x)/F	Ys(x)	e(x)	g(x)
14.4	0.0018	-1.8444	0.976	-2.402
19.5	0.1151	-0.7712	1.3364	-1.4501
24.5	0.3528	-0.041	1.4184	-0.743
29.5	0.5869	0.6294	1.2978	-0.0382
34.5	0.7795	1.3897	0.967	0.8356
39.5	0.9192	2.4736	0.4509	2.1649
44.5	0.9889	4.4984	0.0462	4.4564
49.5	0.9999	9.3416	-	-

Source: International Population Conference, Manila, 1981, p.360

Table 4.3(b):
Standard values for mean parities and their ratios.

Age	i	Pi/F	Ys(i)	e(i)	g(i)
15-19	1	0.0528	-1.0787	1.2897	-1.7438
20-24	2	0.2551	-0.3119	1.4252	-1.0157
25-29	3	0.4956	0.3538	1.3725	-0.3353
30-34	4	0.7064	1.0569	1.1421	-0.4391
35-39	5	0.8678	1.9534	0.7061	1.5117
40-44	6	0.9676	3.413	0.2763	3.2105
45-49	7	0.9977	6.0557	-	-

Source: International Population Conference, Manila, 1981, p.360

Step 5: $\hat{P}(i) = e^{-e^{-\hat{Y}(i)}}$ and $\hat{F}(x) = e^{-e^{-\hat{Y}(x)}}$

where $\hat{Y}(i) = a + bYs(i)$ and $\hat{Y}(x) = a + bY(x)$.

Step 6: Estimation of a and b.

$$b = \frac{\sum\{[(z(i)-e(i))*(g(i))^2] - [(z(i)-e(i))*\sum g(i)]\}/5}{[\sum(g(i))^2 - (\sum g(i))^2]/5}$$

$$a = [\sum(z(i)-e(i)) - b(\sum g(i))]/5.$$

Step 7:

Ti = Pi/P^i or Tx = F(x)/F^(x).

Total fertility rate for various age groups, T(i) are averaged to obtain estimates for all groups.

Computation for Kenya at the national level is illustrated in tables 4.3(d) and 4.3(e).

Table 4.3(c): Measures For the Gompertz Model.

Ys(i)	e(i)	g(i)	g(i)sqd	Ys(X)	e(X)	g(X)	g(X)sqd
-1.0787	1.2897	-1.7438	3.040838	-0.7712	1.3364	-1.4501	2.102790
-0.3119	1.4252	-1.0157	1.031646	-0.041	1.4184	-0.743	0.552049
0.3538	1.3725	-0.3353	0.112426	0.6294	1.2978	-0.0382	0.001459
1.0569	1.1421	0.4391	0.192808	1.3897	0.967	0.8356	0.698227
1.9534	0.7061	1.5117	2.285236	2.4736	0.4509	2.1649	4.686792
3.413	0.2763	3.2105		4.4984	0.0462	4.4564	
6.0557		-1.144	6.662956	9.3416		0.7692	8.041317

Source: International Population Conference, Manila,1981, p.360

Table 4,3(d): Estimation of Total Fertility by Fitting the Relational Gompertz Model to P(i) values, Kenya.

Age(X)	P(i)	P(i)/P(i+	Z(i)	Z(i)-e(i)	Y
15-19	0.320578	0.172882	-0.56254	-1.85224	3.229952
20-24	1.854308	0.511859	0.400919	-1.02428	1.040361
25-29	3.622686	0.675573	0.935998	-0.43650	0.146358
30-34	5.36239	0.832287	1.695119	0.553019	0.242830
35-39	6.442954	0.885760	2.109416	1.403316	2.121393
40-44	7.273924	0.955022			
45-49	7.616494			-1.35669	6.780897

Age(X)	b	Y^(i)	P^(i)	P(i)/P^(i)
15-19	1.010822	-1.13043	0.045184	7.094927
20-24	a	-0.35533	0.240108	7.722786
25-29	-0.04006	0.317565	0.482912	7.501736
30-34		1.028274	0.699336	7.667825
35-39		1.934477	0.865455	7.444585
40-44		3.409873	0.967494	7.518309
45-49		6.081173	0.997717	7.633921
Mean estimate of Total Fertility				7.512013

The procedure is illustrated by obtaining total fertility for the first age group, T(1):

$$Z(1) = -\ln[-\ln(P(1)/P(2))]$$

$$= -\ln[-\ln(0.172882)] = -0.56254.$$

Obtain values for e(i) from Table 4.3(c) and

$$Z(1)-e(1) = (-0.56254 - 1.0632) = -1.85224.$$

1.2897

$$b = \frac{6.780897 - [(-1.35669)*(-1.144)]/5}{[6.6662956 - 1.308736]/5}$$

$$= 1.010822.$$

$$a = \{ -1.35669 - [(1.010822)(-1.144)]\}/5$$

$$= -0.04006.$$

$$Y\hat{}(1) = a+bYs(1)$$

$$= (-0.04006)+(1.010822)(-1.0787)$$

$$= -1.13043$$

$$P\hat{}(1) = e^{-e^{-Y\hat{}(1)}}$$

$$= e^{-e^{(-1.13043)}}$$

$$= 0.045184.$$

$$T(1) = P(1)/P\hat{}(1) = 0.320578/0.45184$$

$$= 7.094927$$

All T(i) for i = 2 through 7 were calculated in this manner.

The mean estimate of total fertility for Kenya from mean parities was 7.512013, and 6.598757 from current births.

Table 4.3(e): Estimation of Total Fertility by Fitting the Relational Gompertz Model to F(i) values, Kenya.

Age(X)	F(X)	F(X)/F(X+	Z(X)	Z(X)-e(X)	Y
15-19	0.53867	0.268634	-0.27338	-1.60978	2.334346
20-24	2.005215	0.567922	0.569567	-0.84883	0.630682
25-29	3.53079	0.728154	1.148088	-0.14971	0.005718
30-34	4.84896	0.821629	1.627265	0.660265	0.551718
35-39	5.90164	0.911536	2.379214	1.928314	4.174607
40-44	6.474385	0.957279			
45-49	6.76332			-0.01974	7.697073

Age(X)	b	Y^(X)	F^(X)	F(X)/F^(X)
15-19	0.971870	-0.90296	0.084846	6.348779
20-24	a	-0.19330	0.297227	6.746396
25-29	-0.15346	0.458233	0.531315	6.645379
30-34		1.197145	0.739297	6.558876
35-39		2.250555	0.900017	6.557247
40-44		4.218398	0.985385	6.570407
45-49		8.925359	0.999867	6.764219
Mean estimate of Total Fertility				6.598757

4.4 Fitting the Relational Gompertz Model to Kenya's Data.

In practical application a chosen set of standard fertility rates, Ys(x), should be an average which minimises deviation from linearity for individual sets of Y(x) values in their relation to the standard. Booth (1979) used a selection of Coale-Trussell models that seemed most appropriate for high fertility populations to derive such a standard set of rates shown in Table 4.3(c).

The model was fitted to both P(i) and F(i) data for districts to estimate total fertility rates. These are presented in Table 4.4.1.

Total fertility rates obtained by fitting the model to P(i) data seems to reflect the same fertility levels as able 4.4.1: Total Fertility Estimates Obtained by Fitting The Gompertz Model To P(i) and F(x) Data.

REGION	P(i)	F(x)	Average	REGION	P(i)	F(x)	Average
KENYA	7.512	6.599	7.0555	R.VALLEY	8.044	6.612	7.328
NAIROBI	4.54	-	-	BARINGO	8.101	8.149	8.125
CENTRAL	7.323	4.816	6.069	MARAKWET	4.598	2.568	3.583
KIAMBU	8.054	5.549	6.8015	LAIKIPIA	7.909	5.979	6.944
IRINYAGA	7.871	5.395	6.633	NAKURU	6.737	-	-
MURANGA	8.81	6.522	7.666	KERICHO	8.631	-	-
YANDARUA	7.512	5.391	6.4515	NANDI	8.618	6.906	7.762
NYERI	7.323	4.816	6.0695	NAROK	7.843	7.216	7.5295
COAST	6.862	5.452	6.157	SAMBURU	7.457	8.627	8.042
KILIFI	7.097	6.455	6.776	T.NZOIA	7.354	4.269	5.8115
KWALE	7.308	5.255	6.2815	KAJIADO	6.874	-	-
LAMU	7.607	6.326	6.9665	W.POKOT	7.629	6.819	7.224
MOMBASA	4.743	3.823	4.283	TURKANA	6.793	2.39	4.5915
TAITA	8.326	6.118	7.222	U.GISHU	7.54	6.613	7.0765
T.RIVER	8.608	6.224	7.416				
EASTERN	7.248	4.785	6.0165				
EMBU	7.469	5.177	6.323				
ISIOLO	5.912	8.524	7.218				
KITUI	7.562	5.517	6.5395				
ACHAKOS	7.786	4.886	6.336				
ARSABIT	4.985	4.903	4.944				
MERU	6.699	5.271	5.985				
.EASTERN	6.785	3.491	5.138				
GARISSA	7.431	2.802	5.1165				
MANDERA	6.424	4.911	5.6675				
WAJIR	6.334	3.305	4.8195				
NYANZA	7.766	5.556	6.661				
KISII	9.314	6.217	7.7655				
SIAYA	7.105	5.549	6.327				
S.NYANZA	7.584	5.451	6.5175				
KISUMU	6.865	5.957	6.411				
WESTERN	8.054	5.18	6.617				
KAKAMEGA	7.585	3.518	5.5515				
BUNGOMA	8.872	6.607	7.7395				
BUSIA	7.329	5.647	6.488				

those suggested by the P/F Ratio methods and the P3/P2[2] formula. F(x) values are markedly lower. As was the case in the P/F Ratio methods it is implied that current births information differs from average parity data reported by the same women. In fitting the model to current fertility data, F(x), reporting errors were more evident. For a number of districts especially in Rift Valley Province fitting the model to F(x) data did not work well for women aged above forty years. F(x) values were too low for these ages and they were eliminated in the estimation of total fertility rates.

For women aged 20 to 40 and where the parameters a and b are within the limits $-0.3 < a < 0.3$, and $0.8 < b < 1.25$ technical limitations are not important (Zaba, 1981,p.9),but F(x) values are suspect. For instance beta values for Western Province (1.39), Nyeri (1.83), Kericho (-52.178), Eastern Province (1.428) and many Rift Valley districts are out of acceptable range.

Comparison of intercensal estimates with those obtained by fitting the model to 1969 and 1979 data separately (Osiemo, 1986) reveals no substantial differences. Individual estimates show a consistent increase in levels from 1969 to 1979, except for Busia and Trans-Nzoia Districts. In common with other techniques that are pre-adjusted using the additive synthetic technique (Chapters Two and Three), intercensal estimates do not necessarilly fall in between 1969 and 1979 levels. About half the districts' levels are higher than the 1979 ones. Curiously, fertility levels in nine districts are below both censuses', although fertility levels rose from 1969 to 1979.

4.5 ANALYSIS OF INFORMATION ON MEAN PARITIES AND ON CURRENT FERTILITY, KENYA.

Estimates obtained by fitting the model to P(i)'s seem to be reliable. Figure 4.5(a) shows a very good linear relation between z(i)-e(i) and the standard g(i) up to age forty. From current fertility z(x)-e(x) values have also good linear relation with g(x), but the fit is less succesful. The cohort aged 25 to 29 years is way out of line with the graph points for other age groups. [Figure 4.5(b)].

4.5.1 Reporting Errors Affecting Fertility Level and Shape.

There is reason to believe that Kenya's data on current births suffers serious error. That fact notwithstanding Figure 4.5(b) demonstrates a reasonably good fit of the model distribution to data on current births. "If the only type of error present in the reporting of births in the last year is mother (such as might be caused by reference period errors), then the shape of the fertility distribution is not affected, and fitting a model distribution presents no problem". (Zaba, 1981, p.2). The shape of fertility distribution from current-births data is mainly distorted by age misrepoting, a common error believed to affect Kenya's data besides reference period errors. One might have expected a distorted fertility distribution, but this is not evident. Figure 4.5(c) shows a comparison of Kenya's fertility distribution with Booth's standard schedule.

Table 4.5.1 Fertility Schedules, Kenya and the Standard.

KENYA		STANDARD	
Age	f(i)	x	fs(x)
15-19	0.107734	17	0.02783
20-24	0.293309	22	0.04904
25-29	0.305115	27	0.04642
30-34	0.263634	32	0.03754
35-39	0.210536	37	0.02462
40-44	0.114549	42	0.01218
45-59	0.057787	47	0.00133

Fig. 4.5(a) FITTING MODEL TO SYNTHETIC DATA (INTERCENSAL) P(i)- DATA

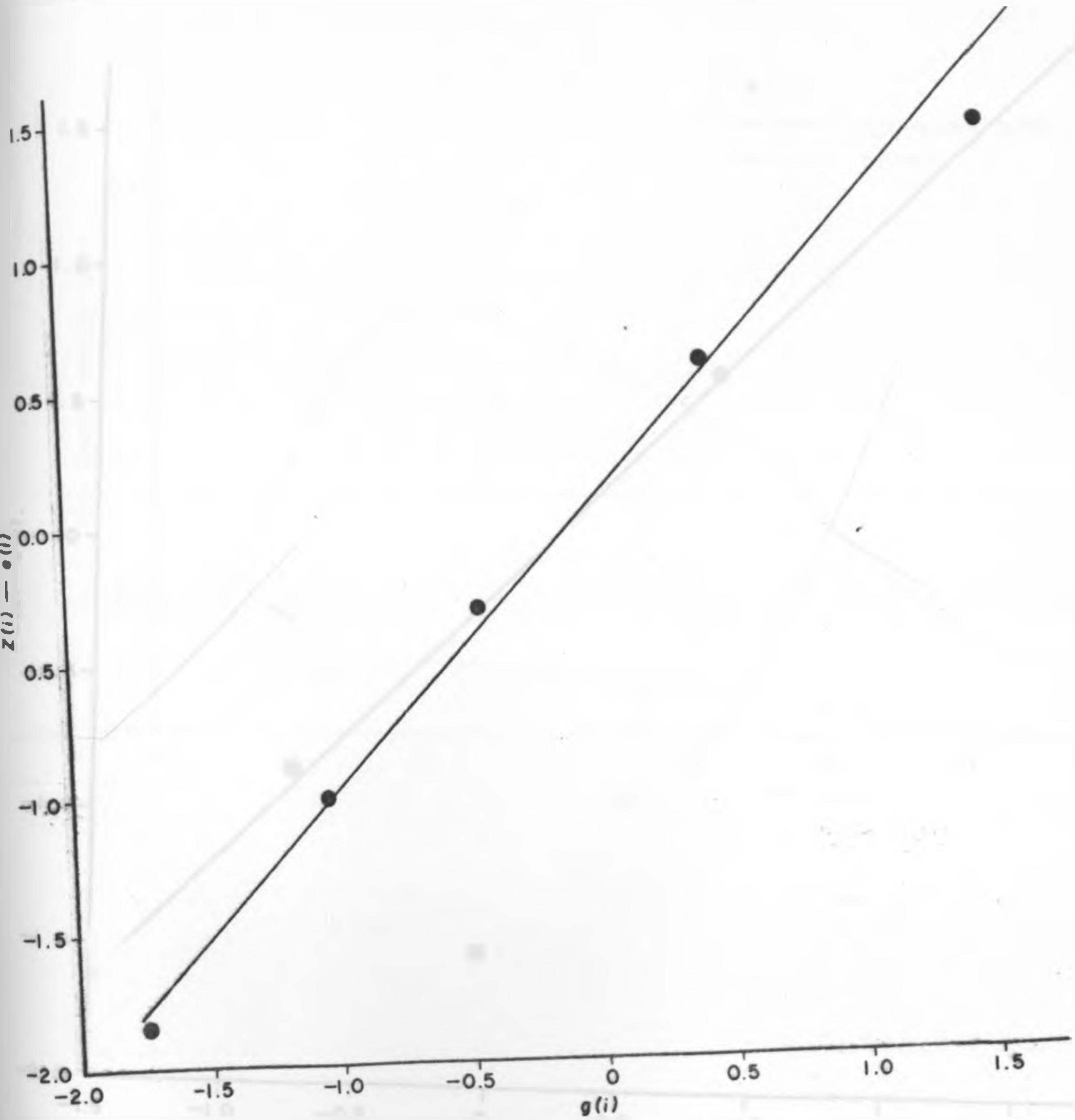


Fig. 4 5(b) MODEL TO INTERCENSAL (SYNTHETIC) DATA, KENYA F(x) DATA

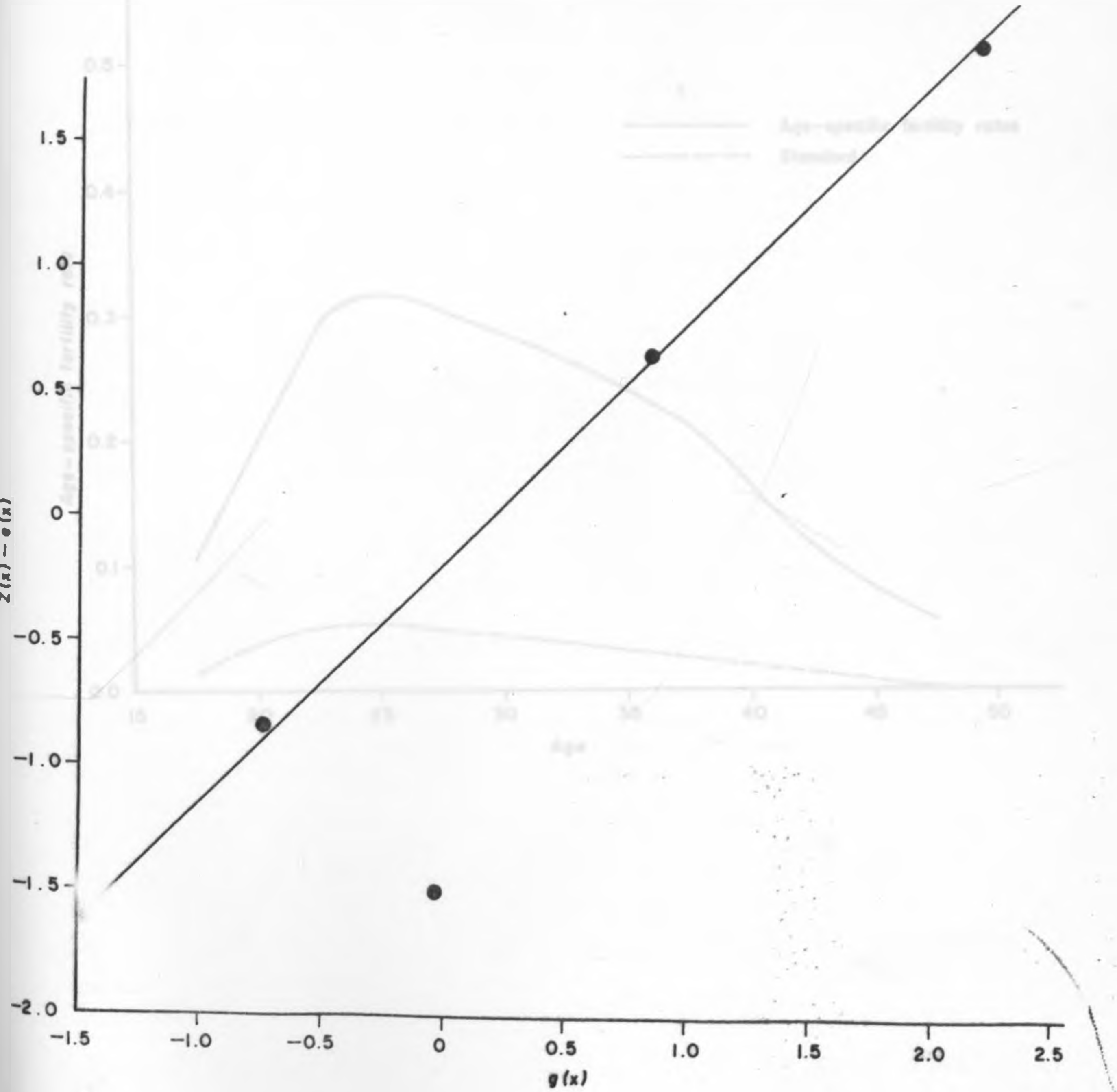
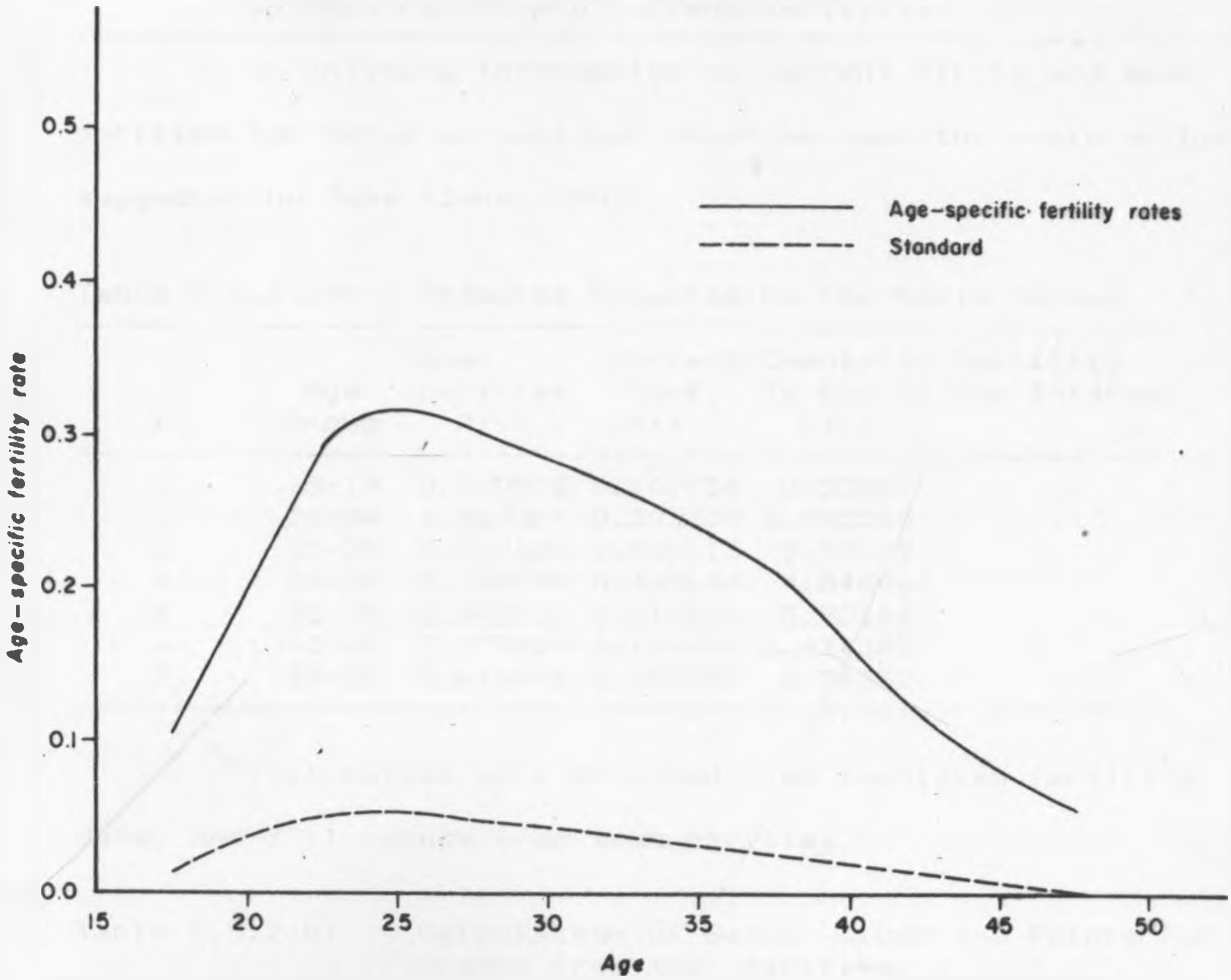


Fig. 4.5(c) COMPARISON OF AGE-SPECIFIC FERTILITY RATES, KENYA WITH STANDARD AGE-SPECIFIC FERTILITY RATES



4.5.2 Fertility Pattern Obtained By Combining Information On Mean Parity and Current Fertility.

In anlysing information on current births and mean parities for Kenya at national level we used the ratio method suggested by Zaba (Zaba, 1981).

Table 4.5.2(a): Measures Required by the Ratio Method.

i	Age Group	Mean parities P(i)	Current Fert. f(i)	Cumulated Fertility To End Of Age Interval F(x)
1	15-19	0.320578	0.107734	0.53867
2	20-24	1.854304	0.293309	2.005215
3	25-29	3.622686	0.305115	3.53079
4	30-34	5.362390	0.263634	4.84896
5	35-39	6.442954	0.210536	5.90164
6	40-44	7.273924	0.114549	6.474385
7	45-59	7.616494	0.057787	6.76332

Y(x) values were obtained from cumulated fertility data, and Y(i) values from mean parities.

Table 4.5.2(b) Calculation of Gamma Values and Points For Graphs From Mean Parities.

Groups i/i+1	r = Pi/Pi+1	Y = -ln[-lnr]	Y+Q'-Q	Q'
1/2	0.17288	-0.5625	-1.6257	-2.6447
2/3	0.51186	0.4009	-0.8888	-1.7437
3/4	0.67557	0.936	-0.4892	-1.0157
4/5	0.83228	1.6951	0.323	-0.33549
5/6	0.88576	2.1094	0.9673	0.4391
6/7	0.95502	3.0786	2.3725	1.5116

In Figure 4.5(d) Y(x)+Q'x-Qx is plotted against Q'x to reveal at which ages the shape of fertility distribution depart from the model form. In the same figure Y(i)+Q'i-Qi is plotted against Q'i.

Table 4.5.2(c) Calculation of Gamma Values and Points For Graphs From Cumulated Fertility Rates.

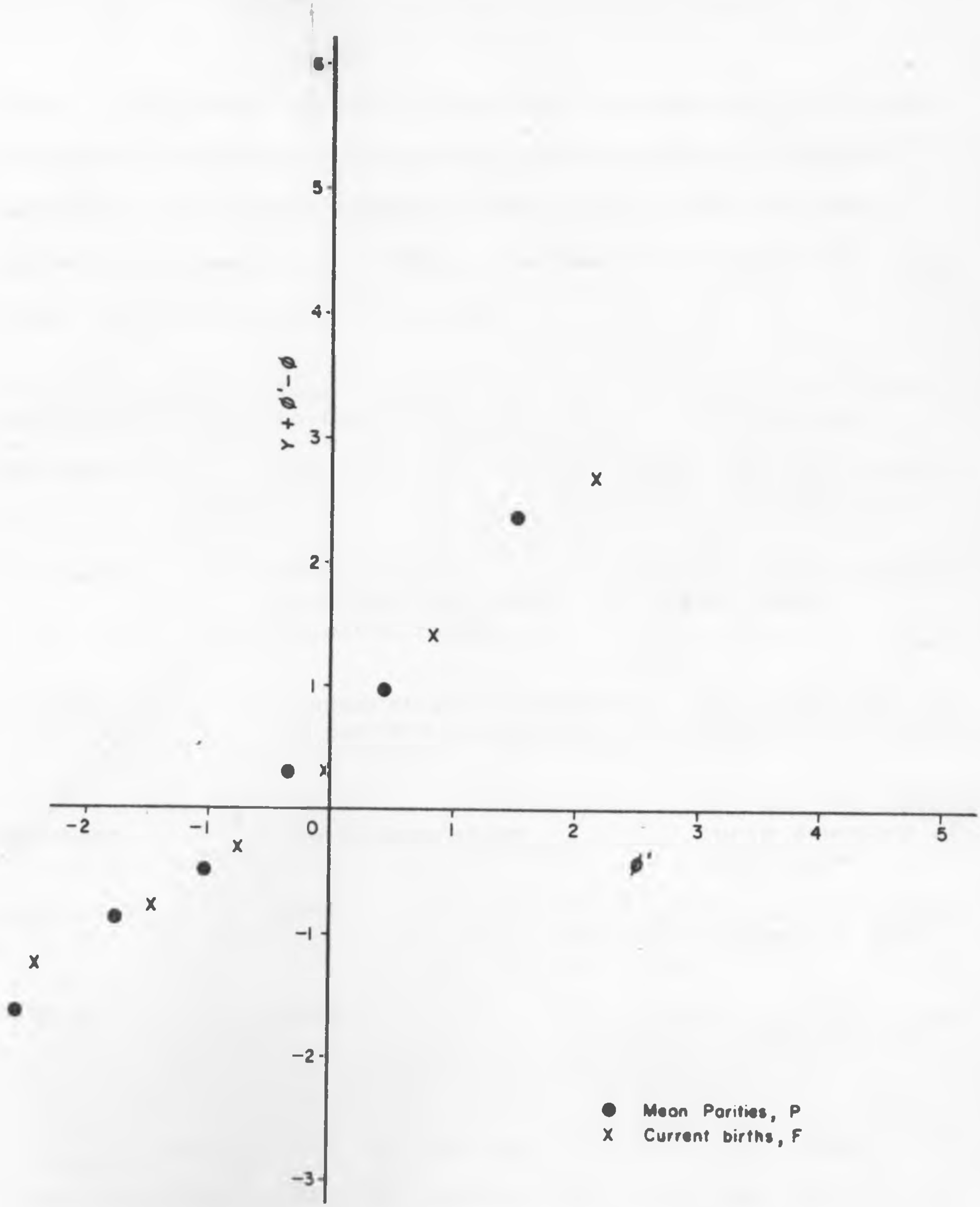
Groups x/x+5	r = Fx/Fx+5	Y = -ln[-lnr]	Y+Q'-Q	Q'
1/2	0.2687	-0.2734	-1.2494	-2.4019
2/3	0.5679	0.5696	-0.7668	-1.4501
3/4	0.7282	1.1481	-0.2703	-0.7429
4/5	0.8216	1.6273	0.3296	-0.0381
5/6	0.9115	2.3792	1.4122	0.8356
6/7	0.9573	3.1318	2.6809	2.1649

Theoretically if fertility has been constant, points plotted for mean parities and for cumulated fertility would lie the same straight line. Where deviations exist, errors in data are implied. If fertility has been changing, the line suggested by graph points from mean parities would differ from those plotted from cumulated fertility.

Plots for the two sets of data in Figure 4.5(d) almost lie in a straight line, if somewhat warped. But we may not be certain in assuming that this indicates constant fertility during the period under consideration: The additive synthetic technique used in preliminary adjustment of data provides for the assumption of constant fertility even if fertility has been changing by adjusting the data such that it can be utilised by techniques that demand constant fertility.

Excepting the plots for the youngest and the oldest age groups the 'F' points donot deviate from the 'P' points. So either fertility has not been changing or this trend results from the effect of the adjustment technique. That the plots do not strictly fall in a straight line is a manifestation of

Fig. 4.5 (d) FERTILITY PATTERN FROM A COMBINATION OF MEAN PARITIES AND CUMULATED FERTILITY RATES, KENYA



error in the basic data. It is beyond the scope of this study to delve into detailed error analysis. However, it may be worthwhile to discuss Figure 4.5(d) in the light of ideal patterns that may emerge from a combination of fertility level trends and the type of data error.

True Trend in Fertility Level	Type of Error in Data	Effect on Plots of Y values
Constant	None	'F' points and 'P' points lie on one straight line
Constant	Omission of children ever born by older women	'P' points curve upwards at older ages
Constant	Exaggeration of number of current births to older women	'F' points curve downwards at older ages
Constant	Age exaggeration	'F' and 'P' points curve downward at older ages
Falling	None	'P' line has gentler slope and lower intercept than 'F' line
Rising	None	'P' line has steeper slope and higher inercept than 'F' line

Leaving aside the youngest and the oldest women, the trend suggested is that of constant fertility but there is no evidence of omission of children ever born by older women or of exaggeration of the number of current births to older women. Also, it is not possible to detect age exaggeration from the trends. It is likely that real trends might have been eclipsed by a complex mixture of many types of error.

Some types of error must have originated in the additive synthetic adjustment technique. When analysed separately, data from the two censuses exhibit similar characteristics. In both cases there are very good fits of model distributions to data on current births and average parities.(Figures 4.5(e), 4.5(f), 4.5(h), and 4.5(i)). Also in both cases fertility patterns analysed - a la Zaba (Zaba,1981) - from a combination of mean parities and cumulated fertility rates indicate omission of children ever born by older women. (Figures 4.5(g) and 4.5(j)).

4.6 CONCLUSION.

The relational Gompertz model yielded acceptable total fertility estimates. These are about the same level as those calculated by the Coale-Demeny formula, and slightly lower than the estimates obtained by the P/F Ratio methods (Chapters Two and Three).

Like in the P/F ratio methods, information on current births differs from infromation on average parities reported by the same women. Notably, fitting the Gompertz model to current fertility data was less successful especially for women aged forty years: Apart from suggested reporting errors, total fertility rates obtained by fitting the model to F(x) data are too low.

Effects of reporting errors on fertility level and shape are not overtly evident. But a combination of errors is suggested. The true pattern of errors must have been obscured by a combination of several types of errors.

CHAPTER FIVE.

5.0 ESTIMATING CRUDE BIRTH RATE, NET REPRODUCTION RATE, GROSS REPRODUCTION RATE, TOTAL FERTILITY RATE AND THE MEAN AGE AT BIRTH USING THE AGE-SPECIFIC GROWTH RATE ADJUSTMENT TECHNIQUE.

5.1 INTRODUCTION.

In the foregoing chapters intercensal total fertility rates have been estimated, using techniques that assume constant fertility in the past ten to fifteen years preceeding census, but whose applicability under situations of changing fertility has been facilitated by the additive synthetic adjustment technique. The age-specific growth rate technique discussed in this chapter neither requires that fertility be constant nor population be stable. It only requires both the sexes' age distribution classified by five-year age group and a life table that is appropriated for the intercensal period.

5.2 AGE-SPECIFIC GROWTH RATES.

The frequency distribution of age in a presumed stable population is described in Chapter One (1.5.12) as

$$c(a) = b \exp(-ra)\, p(a).$$

In the equation the growth rate, r is assumed to be constant and uniform for all ages. The age-specific growth rate technique modifies the equation to assume constant growth only within specified age groups (in this case,five-year age groups) and not for all ages. The equation becomes:

$$c(a) = b\, p(a) \exp\left(-\int_0^a r(x)dx\right) \qquad (5.2.1)$$

where c(a) is the population's proportion of persons aged "a", p(a) is the probability of surviving to age "a" , and "r" is the growth rate, a function of age, x.

The age-specific growth rate between age "a" and "a+5" obtained by:

$$ {}_5r_a = \frac{1}{t2 - t1} \ln \left[\frac{{}_5N_a(t2)}{{}_5N_a(t1)} \right] \qquad (5.2.2) $$

where ${}_5N_a(t1)$ and ${}_5N_a(t2)$ are the number of persons aged between "a" and "a+5" at the times of enumeration t1 and t2; that is 1969 and 1979, respectively.

5.3 Age-specific Migration Rates.

The rates of natural increase discussed above, however, do not completely account for population change which also entails the component of migration. The effect of the force of migration operates in a manner analogous to that of mortality on an age-distribution. Equation 5.2.1 becomes:

$$ c(a) = b\, p(a) \exp \left(- \int_0^a [\, r(x)+e(x)\,]dx \right) \qquad (5.2.3) $$

where e(x) is the net migration rate with respect to age, x. It is demonstrable that the net out-migration rate between age "a" and "a+5" can be derived from 5.2.3 and expressed:

$$ {}_5e_a = \frac{-1}{5} \ln \left[\frac{N(a+5)}{N(a)} * \frac{p(a)}{p(a+5)} \right] - {}_5r_a \qquad (5.2.4) $$

where N(a) and N(a+5) are the number of persons aged "a" and "a+5", respectively (Appendix 2).

Age-specific migration rates for infants and children under the five years old have to be estimated from their mothers' rates, as intercensal births, N(0), are not available.

5.4 ESTIMATION OF CRUDE BIRTH RATE.

From equation (1.5.13) defined in Chapter One the birth rate may be expressed:

$$b = \frac{1}{\int_0^{\infty} \exp(-(\int_0^{a} r(x)dx)p(a)da} \qquad (5.4.1)$$

Migration included, 5.4.1 may be re-written:

$$b = \frac{1}{\int_0^{\infty} \exp(-(\int_0^{a} r(x)+e(x)\ dx)p(a)da} \qquad (5.4.2)$$

p(a)'s can be obtained by Brass-type procedures based on reported number of children ever born, and of children dead. The procedure for life table construction is in Appendix 1.

In practical application five-year age intervals are considered. The mid-point of ages x and (x+5) is approximated (x+2.5). Thus

$$b = \frac{1}{\int_0^{\infty} \exp(-\int_0^{x+2.5} r(y)+e(y)\ dy)\ 5Lx/lo\ dx} \qquad (5.4.3)$$

where $\int_0^{x+2.5} r(y)+e(y)dy = \int_0^{5} r(y)+e(y)dy + \int_5^{10} r(y)+e(y)dy + \ldots + \int_{x-5}^{x} r(y)+e(y)dy + \int_{x}^{x+2.5} r(y)+e(y)dy$

$= 5[(5r0+5e0)+(5r5+5e5)+(5r10+5e10)+\ldots,$
$+(5r\ x-5\ +5e\ x-5)] + 2.5(5rx+5ex)$,

where (5rx+5ex) is the rate of growth between age x and x+5, assumed to be constant in the five-year interval. Computation of birth rate is in discrete form:

$$b = \frac{1}{\sum_{x=0}^{\infty} \{\exp -[5(5r0+5e0 +\ldots,+5rx-5 +5ex-5)+2.5(5rx+5ex)]\}\ 5Lx/lo}$$

(5.4.4)

This is illustrated in Table 5.4.1 using data for Nairobi District.

Table 5.4.1 Estimation of Crude Birth Rate for Nairobi District

AGE (x) (1)	1969 (2)	1979 (3)	5rx+5ex (4)	5Rx (5)	Exp(-5Rx) (6)	5Lx/l(0) (7)	Product (8)
0-1						0.953446	
1-4	38161	61499	-0.00090	0	1	3.61854	3.61854
5	29275	46055	0.049744	0	0.883061	4.415119	3.898823
10	21077	37341	0.001950	0.049744	0.779798	4.348826	3.391207
15	25095	47388	-0.03540	0.049744	0.779798	4.292395	3.347202
20	28525	52923	0.013175	0.049744	0.754532	4.22047	3.184479
25	20971	38786	0.073975	0.062919	0.606814	4.134545	2.508900
30	13068	22580	0.091804	0.136894	0.400925	4.042492	1.620737
35	9439	13742	0.080418	0.228698	0.260660	3.941757	1.027461
40	6176	8913	0.075646	0.309116	0.176454	3.8261	0.675130
45	4600	5656	0.063010	0.384762	0.146049	3.690519	0.538998
50	3265	4236	0.045489	0.384762	0.130349	3.521929	0.459083
55	3131	2746	0.051368	0.430251	0.102317	3.306498	0.338312
60	1733	1997	0.065583	0.481619	0.076378	3.021835	0.230803
65	1033	1427	0.042278	0.547202	0.058326	2.633558	0.153605
70	693	1060	-0.04489	0.589480	1.118764	2.143679	2.398272
75+	885	1363	0.043185	-0.04489	0.879362	1.303842	1.146549
	207127	347712				SUM =	28.53810

Age-specific growth rates, 5rx, are calculated from the 1969 and 1979 age distributions (columns 2 and 3). Age-specific migration rates for the 1969 to 1979 intercensal period were calculated by Wakajuma (Wakajuma, 1986, p.52). For age 0 to 5 5r0 is 0.047720. Since no migration rates are available for the age-group it is assumed that their movements are similar to their mothers' (cohort aged 15 to 19).That is -0.04772. Hence

$$5r0 + 5e0 = 0.047720 + (-0.04862)$$

$$= -0.00090.$$

Age-specific growth rates, including migration, are cumulated in Column (5). For example, cumulated growth rate up to age forty is obtained by:

$$5r35 + 5e35 = [(5r0+5e5)+(5r5+5e5)+...+(5r30+5e30)+(5r35+5e35)]$$

$$= 0.194348.$$

From an appropriate life table 5Lx/lo is obtained (Column 7) and multiplied for every age group by the result in Column 6. The product is listed in Column 8.

The intercensal birth rate is obtained by the reciprocal of the sum of column 8. That is:

$$b = 1/27.02457$$
$$= 0.037003.$$

Crude birth rates have been computed similarly for other districts (Table 5.4.2). At the national level, no adjustment is required for net out-migration but the procedure remains the same. The effect of emigration is relatively negligible.(1)

Table 5.4.2 Crude birth Rates Obtained by the Age-specific Growth rate Technique and by Osiemo(1986)

REGION	b	Osiemo 1969	1979
KENYA	0.052	0.0532	0.0554
NAIROBI	0.037	0.0388	0.0379
CENTRAL	0.040	0.0495	0.0486
KIAMBU	0.045	0.0493	0.0502
KIRINYAGA	0.048	0.0424	0.0496
MURANGA	0.043	0.0521	0.0471
NYANDARUA	0.050	0.0594	0.0517
NYERI	0.040	0.0461	0.0462
COAST	0.039	0.0359	0.0541
KILIFI	0.054	0.0374	0.0595
KWALE	0.050	0.0371	0.0558
LAMU	0.054	0.0286	0.0458
MOMBASA	0.044	0.0349	0.0497
TAITA	0.052	0.0364	0.0566
T.RIVER	0.052	0.0301	0.0498
EASTERN	0.042	0.0491	0.0528
EMBU	0.049	0.0500	0.0537
ISIOLO	0.042	0.0264	0.0496
KITUI	0.048	0.0631	0.0538
MACHAKOS	0.048	0.0484	0.0531
MARSABIT	0.040	0.0400	0.0434
MERU	0.046	0.0435	0.0524
N.EASTERN	0.047	0.0438	0.0461
GARISSA	0.050	0.0517	0.0503
MANDERA	0.047	0.0246	0.0469
WAJIR	0.044	0.0295	0.0480

Table 5.4.2 Continued...

REGION	b	Osiemo 1969	1979
NYANZA	0.050	0.0418	0.0597
KISII	0.052	0.0418	0.0633
SIAYA	0.045	0.0440	0.0546
S.NYANZA	0.049	0.0418	0.0609
KISUMU	0.046	0.0399	0.0567
WESTERN	0.042	0.0507	0.0581
KAKAMEGA	0.053	0.0513	0.0568
BUNGOMA	0.054	0.0512	0.0598
BUSIA	0.045	0.0467	0.0602
R.VALLEY	0.048	0.0391	0.0541
BARINGO	0.052	0.0302	0.0577
MARAKWET	0.050	0.0361	0.0507
LAIKIPIA	0.043	0.0451	0.0513
NAKURU	0.045	0.0437	0.0534
KERICHO	0.051	0.0364	0.0566
NANDI	0.050	0.0415	0.0527
NAROK	0.048	0.0399	0.0529
SAMBURU	0.043	0.0342	0.0477
T.NZOIA	0.053	0.0517	0.0560
KAJIADO	0.043	0.0574	0.0526
W.POKOT	0.053	0.0270	0.0578
TURKANA	0.040	0.0267	0.0520
U.GISHU	0.047	0.0404	0.0546

Source: Osiemo,A. 1986. Estimation of Fertility Levels and Differencials in Kenya. Msc Thesis. Population Studies and Research Institute. University of Nairobi. p. 169.

5.5 COMPARISON OF BIRTH RATE ESTIMATES.

The age-specific growth rate adjustment technique provides crude birth rates that compare well with those that estimated for the two censuses separately (Table 5.4.2). Osiemo (1986) estimated the latter using the Coale-Trussell fertility model. In the majority of districts birth rates for the intercensal period fall between Osiemo's 1969 and 1979 estimates. It may be reasonable to consider the Age-specific growth rate adjustment technique fairly accurate in the estimation of crude birth rates.

It is also worth noting that the life tables on which the technique relies fundamentally, have been constructed using using the Coale-Trussell model of mortality (Appendix 1). Arguably this may be a factor explaining the conformity between birth rate estimates obtained by the Coale-Trussell model and the age-specific growth rate technique.

Inter-district migration has in the past affected fertility estimation by methods based on the Stable Population model (Mwobobia, 1982). Its effect on the performance of the age-specific growth rate technique is considerable. An attempt to estimate crude birth rates by relying only on natural increase (Equation 5.4.1) produced birth rate estimates that were unreasonably high. For example Nairobi had a crude birth rate of 64 births per thousand population; Lamu had 106, Tana and Marsabit,88; Garissa, 94; West Pokot, 103, and so on.

Table 5.4.3: Crude Birth Rates Estimated Without the Migration Component.

REGION	b	REGION	b	REGION	b
KENYA	0.0518	EASTERN	0.0457	R.VALLEY	0.0543
NAIROBI	0.0640	EMBU	0.0556	BARINGO	0.0457
CENTRAL	0.0391	ISIOLO	0.0560	MARAKWET	0.0178
KIAMBU	0.0470	KITUI	0.0523	LAIKIPIA	0.0890
KIRINYAGA	0.0460	MACHAKOS	0.0504	NAKURU	0.0760
MURANGA	0.0470	MARSABIT	0.0888	KERICHO	0.0429
NYANDARUA	0.0400	MERU	0.0463	NANDI	0.0530
NYERI	0.0370	N.EASTERN	0.0637	NAROK	0.0718
COAST	0.0456	GARISSA	0.0946	SAMBURU	0.0281
KILIFI	0.0559	MANDERA	0.0342	T.NZOIA	0.0992
KWALE	0.0588	WAJIR	0.0720	KAJIADO	0.0730
LAMU	0.1064	NYANZA	0.0459	W.POKOT	0.1030
MOMBASA	0.0543	KISII	0.0420	TURKANA	0.0123
TAITA	0.0484	SIAYA	0.0470	U.GISHU	0.0617
T.RIVER	0.0882	S.NYANZA			
WESTERN	0.0439	KISUMU			
KAKAMEGA	0.0465				
BUNGOMA	0.0570				
BUSIA	0.0680				

5.6 ESTIMATION OF THE FEMALE NET REPRODUCTION RATE, GROSS REPRODUCTION RATE, TOTAL FERTILITY RATE AND THE MEAN AGE OF MOTHERS AT BIRTH OF THEIR CHILDREN.

The net reproduction rate can also be obtained directly from a set of age-specific growth rates, Combining both the intrinsic rates and net out-migration rates. That is (5rx+5ex). If v(a) is the proportion of births occuring to mothers aged a,

$$v(a) = \frac{N(a)\ m(a)}{\int_{\alpha}^{\beta} N(a)\ m(a)da} \qquad (5.6.1)$$

Where N(a) is the number of women aged "a" ;

m(a) is their rate of bearing female children; and α and β are lower and upper ages of child-bearing (Preston and Coale, 1982). This is actually the frequency distribution of mothers' ages at childbearing.

In a stable population model the age distribution at age "a" is both a function of the age-specific growth rate and the prevailing mortality schedule for the past "a" years. Thus equation (5.6.1) may be re-written:

$$v(a) = \frac{N(0)\ \exp(-\int_{0}^{a}[r(y)+e(y)]dy)p(a)m(a)}{\int_{\alpha}^{\beta} N(0)\ \exp(-\int_{0}^{a}[r(y)+e(y)]dy)\ p(a)m(a)\ da} \qquad (5.6.2)$$

The denominator, a characteristic equation mentioned earlier (equation 1.5.5.3), is equal to unity.

$$\text{So, } v(a) = \exp(-\int_{0}^{a}[r(y)+e(y)]dy)\ p(a)m(a), \qquad (5.6.3)$$

and intuitively we can re-arrange this to be

$$p(a)m(a) = v(a) * \exp(\ \ [r(y)+e(y)]dy.$$

The net reproduction rate may be calculated by the integral of the maternity function, p(a)m(a). (Preston and Coale, 1982, p.247). It is conveniently estimated:

$$NRR = \int_{\alpha}^{\beta} p(a)m(a)da = \int_{\alpha}^{\beta} v(a)\ \exp\left(\int_0^a [r(x)+e(y)]dx\right). \qquad (5.6.4)$$

Intercensal age-specific growth rates are obtained by $\int_0^a [r(y)+e(y)]$ as demonstrated above. If $\alpha = 15$ and $\beta = 50$,

$$NRR = \int_{15}^{45} v(a)\ \exp\left(\int_0^a [r(y)+e(y)]dy\right)\ da$$

$$NRR = \int_{15}^{20} v(a)\ \exp\left(\int_0^{17.5} r(y)+e(y)dy\right)da + \int_{20}^{25} v(a)\ \exp\left(\int_0^{22.5} r(y)+e(y)dy\right)da +$$

$$+\ldots+ \int_{45}^{50} v(a)\ \exp\left(\int_0^{47.5} r(y)dy\right)\ da.$$

$$= 5V15\ \exp\left(\int_0^{17.5} r(y)+e(y)dy\right) + 5V20\ \exp\left(\int_0^{22.5} r(y)+e(y)dy\right) + \ldots$$

$$+ 5V45\ \exp\left(\int_0^{47.5} r(y)+e(y)dy\right), \text{ where}$$

$$\int_0^{x+2.5} r(y)+e(y)dy = 5(5r0+5e0 + 5r5+5e5 +\ldots,+ 5rx-5+5ex-5)$$

$$+2.5(5rx+5ex).$$

$$NRR = \sum_{x=15}^{50} 5Vx\ [\exp(5\ (5r0+5e0\ +5r5+5e5\ +\ldots+\ 5rx-5+5ex-5)\ +$$

$$2.5(5rx+5ex))].$$

The gross reproduction rate,GRR can be esimated from NRR, once an appropriate life table (p(a)'s) had been obtained for the intercensal period (Appendix 1).

$$GRR = \int_{\alpha}^{\beta} \frac{v(a)}{p(a)}\ \exp\left(\int_0^a r(y)+e(y)dy\right)\ da \qquad (5.6.5)$$

$$= \sum_{x=15}^{50} 5Vx/p(x)\ [\exp(5(5r0+5e0\ +\ 5r5+5e5+\ldots+5rx-5+5ex-5)$$

$$+2.5(5rx+5ex))].$$

Ideally, the probability of surviving to the mean age of the net maternity function, $p(\bar{m})$, if known, is employed in equation (5.6.5) in the place of p(a).

The total fertility rate may be approximated from GRR if the sex ratio at birth is known, by the relation:

$$TFR = GRR(1+SRB) \qquad (5.6.6)$$

where SRB is the ratio of male to female births, estimated in Kenya to be about 1.05.

Table 5.6.1 illustrates the above procedure as applied to Kenya at the national level.

Table 5.6.1: Calculation of NRR, GRR and TFR, Kenya.

AGE GROUP (1)	FPOP 1969 (2)	FPOP 1979 (3)	BIRTHS 1969 (4)	BIRTHS 1979 (5)	5va 1969 (6)	5va 1979 (7)	Synthetic p(a) (8)
0-4	1046380	1421385					
5-9	893359	1244749					
10-14	663808	1023839					
15-19	544847	887722	60678	95638	0.129308	0.142424	0.800731
20-24	450096	686003	128341	201211	0.273501	0.299644	0.784634
25-29	411245	541261	118472	167023	0.252470	0.248731	0.763736
30-34	299241	412691	75992	105123	0.161943	0.156549	0.741579
35-39	264819	325367	51698	63486	0.110171	0.094543	0.717837
40-44	201936	273702	23982	28442	0.051106	0.042355	0.691726
45-49	163852	221965	10088	10577	0.021498	0.015751	0.662025
							0.628722
			469251	671500			

AGE GROUP	AVERAGE 5Va (9)	ASGR 5rx (10)	CUSUM 5Rx (11)	Exp(5Ra) (12)	p(a)m(a) (13)	p(a+2.5) (14)	5ma (15)
0-4		0.030629	0				
5-9		0.033170	0.030629				
10-14		0.043332	0.063799				
15-19	0.135707	0.048815	0.107131	1.930341	0.261962	0.754896	0.347017
20-24	0.286274	0.042142	0.155947	2.423204	0.693702	0.737251	0.940929
25-29	0.250593	0.027471	0.198089	2.883844	0.722673	0.716739	1.008279
30-34	0.159223	0.032144	0.225560	3.347335	0.532974	0.694868	0.767015
35-39	0.102058	0.020590	0.257705	3.819058	0.389768	0.671105	0.580785
40-44	0.046526	0.030408	0.278296	4.338389	0.201848	0.644488	0.313192
45-49	0.018401	0.030355	0.308705	5.050132	0.092931	0.614436	0.151245
				NRR =	2.895860	GRR =	4.108466
		1+SRB =	2.05	TFR =	8.422356		

From columns 2 and 3 we obtain 5rx, listed in Column 10. For provinces and districts these are adjusted for migration to be (5rx+5ex). The cumulated sums of growth rates up to various age groups are listed in Column 11.

Proportions of births, 5Vx are obtained by dividing births to women in age group x to x+5 in the twelve months preceding each census (columns 4 and 5) by the respective sums of all births for that period. The geometric average of 1969 and 1979 proportions of births is calculated for each age group and listed in Column 9.

Column 12 lists, for every age-group, the exponent of the cumulated age-specific growth rates up to that age. For example, for age 15 to 19

exp(5R15) = exp[(2.5*0.048815)+ (5* 0.107131)]

= 1.930341.

The maternity function, p(a)m(a), for each age group is calculated by the product of exp(5Rx) and the proportions of births, 5Vx (Columns 9 and 12).

From a life table constructed for the 1969 to 1979 intercensal period we obtain p(a) for each age group a to a+5 (Column 8). Further we obtain the probability of surviving to the mid-year of each age group. That is p(a+2.5) in Column 14 is estimated from p(a) and p(a+5). For example

p(15+2.5) = sqrt(0.800731 * 0.784634)/1.05

= 0.754896.

Column 15 lists the quotient of Columns 13 and 14. That is [5Vx exp(5Rx)/p(x+5)]. The net reproduction rate is obtained by summing up the values of Column 13; while the gross reproduction rate is obtained by the sum of Column 15.

NRR = 0.261962+0.693702+0.722673+0.532974+0.389768+0.201848 +0.092931

= 2.89586.

GRR = 0.344083+0.940912+1.008262+0.767015+0.580785+0.313192 +0.151245

=4.105497.

The total fertility rate is computed from the gross reproduction rate:

$$TFR = GRR(1+ SRB)$$

$$= 4.105497(1+ 1.05)$$

$$= 8.422356.$$

It is also possible to approximate the mean age at birth:

$$m = \frac{1}{NRR}\int_{\alpha}^{\beta} ap(a)m(a)da. \qquad (5.6.7)$$

If the effect of mortality on the maternity function is not desired, this may alternativelly be estimated:

$$m = \frac{1}{GRR}\int_{\alpha}^{\beta} am(a)\, da. \qquad (5.6.8)$$

Table 5.6.2: Calculation of Mean age at Birth, Kenya.

AGE (1)	ap(a)m(a) (2)	am(a) (3)
17	4.453366	5.899304
22	15.26144	20.70045
27	19.51218	27.22355
32	17.05518	24.54449
37	14.42142	21.48907
42	8.477639	13.15406
47	4.367760	7.108558
	83.54901	120.1195
mean-age	28.85118	29.23706

The mean age in each five-year age group is multiplied by its corresponding value of the maternity function and is here listed in Column 2. Mortality not considered, the mean age is multiplied by its corresponding value in Table 5.6.1, Column 15 and listed here in Column 3.

Table 5.6.3 Fertility Parameters Estimated by the Age-specific Growth Rate Technique.

REGION	NRR	GRR	TFR	ap(a)m(a)	am(a)
KENYA	2.895	4.108	8.422	28.85	29.24
NAIROBI	1.587	2.039	3.249	28.86	29.13
CENTRAL	2.975	3.530	6.961	29.94	30.09
KIAMBU	3.126	3.943	7.288	30.03	30.29
KIRINYAGA	3.090	4.424	8.207	30.03	30.42
MURANGA	3.098	3.836	8.208	29.99	30.24
NYANDARUA	3.685	4.569	8.661	29.93	30.17
NYERI	3.271	3.734	7.651	29.82	29.93
COAST	1.780	2.509	4.233	28.73	29.08
KILIFI	2.603	4.123	6.741	33.57	34.07
KWALE	2.517	3.963	6.997	29.06	29.61
LAMU	2.143	3.831	6.156	31.03	31.72
MOMBASA	2.018	2.863	3.863	32.04	32.46
TAITA	2.845	4.203	9.092	28.94	29.32
T.RIVER	2.661	4.365	7.555	35.15	35.62
EASTERN	2.142	3.025	6.202	29.19	29.57
EMBU	2.909	4.123	8.452	34.69	35.03
ISIOLO	2.170	3.127	6.411	33.84	34.28
KITUI	2.435	3.638	7.457	29.17	29.57
MACHAKOS	3.046	4.132	8.471	34.69	35.04
MARSABIT	1.914	2.575	5.278	32.23	32.52
MERU	2.984	3.901	7.998	35.03	35.36
N.EASTERN	2.451	3.324	6.815	30.26	30.58
GARISSA	2.610	3.703	7.591	29.95	30.33
MANDERA	2.476	3.537	7.252	30.96	31.38
WAJIR	2.241	3.157	6.472	29.82	30.17
NYANZA	2.692	3.814	7.820	29.30	29.66
KISII	3.184	4.315	8.846	29.87	30.22
SIAYA	1.880	3.300	6.766	28.27	28.83
S.NYANZA	1.995	3.512	7.199	28.45	29.08
KISUMU	1.699	2.975	6.099	27.89	28.49
WESTERN	2.321	3.175	6.509	28.98	29.26
KAKAMEGA	3.003	4.454	9.130	29.11	29.54
BUNGOMA	3.063	4.479	9.183	29.39	29.79
BUSIA	1.957	3.345	6.858	28.42	28.97
R.VALLEY	2.701	3.471	7.116	28.97	29.23
BARINGO	2.435	4.005	8.210	29.69	30.26
MARAKWET	2.635	4.221	8.653	28.92	28.24
LAIKIPIA	2.817	3.537	7.251	28.26	28.49
NAKURU	2.660	3.380	6.929	29.51	29.79
KERICHO	3.122	4.100	8.405	29.22	29.22
NANDI	2.855	3.925	8.046	28.55	28.94
NAROK	2.638	3.508	7.193	28.81	29.16
SAMBURU	2.496	3.149	6.456	29.91	30.17
T.NZOIA	2.533	3.408	6.988	26.44	26.73
KAJIADO	2.487	3.166	6.491	29.70	29.55
W.POKOT	2.064	3.596	7.372	28.04	28.61
TURKANA	1.656	2.339	4.795	28.93	29.43
U.GISHU	2.633	3.480	7.135	29.03	29.34

The mean age at birth, with maternal mortality taken into account, is obtained by dividing the sum of Column 2 by the net reproduction rate. That is:

m = 83.54901/2.89586

= 28.85118.

Without the mortality component the mean age at birth is estimated by dividing the sum of Column 3 by the gross reproduction rate:

m = 120.1195/4.108466

= 29.23706.

5.7 DISCUSSION OF FERTILITY LEVELS GENERATED BY THE AGE-SPECIFIC ADJUSTMENT TECHNIQUE.

Having compared intercensal birth rates adjusted by the age-specific growth rate technique with those estimated by the coale-Trussell model for separate censuses (Section 5.5) we now compare total fertility rates. The age-specific growth rate technique generates total fertility estimates that are more or less the level of those computed by the Coale-Demeny formula,the Coale-Trussell model and those obtained by fitting the Gompertz relational model to F(i,s) data.

While the level of total fertility is generally similar for these techniques, wide deviations are observable in individual districts, sometimes as wide as one child per woman. Metropolitan districts, visually Nairobi and Mombasa, have rather low total fertility rates compared to those determined by techniques that reflect similar levels in other districts.

Levels of fertility, in common with those determined in previous chapters are undeniably high. The age-specific growth rate technique enables us to infer Kenya's fertility levels relative to replacement level fertility. A net reproduction rate of 1.00 would mean each generation of mothers having exactly enough daughters to replace itself in the population. Table 5.6.3 lists net reproduction rates for Kenya ranging from 1.5 (Nairobi) to 3.6 (Nyandarua). The lowest net reproduction rate suggests - with significant implications on future fertility levels - that a generation of mothers replaces itself one and a half times over.

Table 5.6.3 also reveals that on the average the length of that generation is about twenty-nine years. At national level, for example, within a similar lenghth of time a generation of mothers replaces itself 2.89 times, if current age-specific fertility and mortality rates are maintained. Further, each woman in that generation would bear an average of 8.42 children by the time she reaches menopause.

5.8 EFFECTS OF OTHER POPULATION COMPONENTS ON ESTIMATION OF FERTILTIY PARAMETERS.

The technique fundamentally relies upon age-specific growth rates determined by the population's age distribution. Outside formal mathematical analysis, these growth rates do not separate different forms of attrition or accession. Net in-migration offsets the impact of mortality, among other forms of attrition. The magnitude of the impact of migration may be infered from the difference in the levels of fertility param-

Table 5.6.4 Fertility Parameters Estimated Without Adjustment for Migration.

REGION	NRR	GRR	TFR	ap(a)m(a)	am(a)
KENYA	2.896	4.108	8.422	28.85	29.24
NAIROBI	4.474	5.728	11.744	28.24	28.45
CENTRAL	2.720	3.226	6.613	29.65	29.80
KIAMBU	3.233	4.069	8.343	29.59	29.84
KIRINYAGA	2.767	3.947	8.091	29.46	29.84
MURANGA	3.276	4.057	8.318	30.05	30.28
NYANDARUA	2.529	3.128	6.411	29.24	29.48
NYERI	2.720	3.104	6.363	29.65	29.77
COAST	2.327	3.707	6.704	28.19	28.51
KILIFI	2.891	4.554	9.336	32.79	33.29
KWALE	2.782	4.304	8.823	28.36	28.85
LAMU	6.938	12.557	25.743	31.99	32.70
MOMBASA	2.726	3.832	7.855	30.58	30.98
TAITA	2.366	3.487	7.149	28.56	28.94
T.RIVER	7.474	12.369	25.357	36.71	37.15
EASTERN	2.384	3.361	6.891	28.97	29.34
EMBU	3.272	4.629	9.491	34.44	34.82
ISIOLO	3.157	4.549	9.326	33.78	34.22
KITUI	2.671	3.982	8.162	28.89	29.28
MACHAKOS	3.219	4.359	8.937	34.41	34.76
MARSABIT	7.409	10.046	20.596	33.68	33.95
MERU	2.927	3.817	7.826	34.52	34.85
N.EASTERN	3.895	5.293	10.849	30.59	30.92
GARISSA	9.315	13.72	28.141	35.53	35.94
MANDERA	1.587	2.313	4.741	33.87	34.33
WAJIR	4.853	7.049	14.451	34.49	34.85
NYANZA	2.361	3.329	6.826	28.55	28.89
KISII	2.357	3.168	6.495	28.43	28.75
SIAYA	1.955	3.433	7.038	28.27	28.84
S.NYANZA	1.971	3.449	7.071	27.92	28.51
KISUMU	5.605	9.731	19.949	27.11	27.66
WESTERN	2.365	3.229	6.620	28.59	28.87
KAKAMEGA	2.363	3.492	7.158	28.58	29.00
BUNGOMA	3.146	4.588	9.406	28.97	29.37
BUSIA	3.458	5.936	12.170	28.91	29.47
R.VALLEY	3.268	4.193	8.596	28.57	28.82
BARINGO	2.107	3.431	7.034	28.64	29.16
MARAKWET	0.923	1.489	3.053	26.48	26.43
LAIKIPIA	8.409	10.628	21.788	29.83	30.08
NAKURU	6.420	8.186	16.783	30.20	30.50
KERICHO	2.322	3.032	6.215	28.05	28.36
NANDI	2.942	4.021	8.242	27.57	27.92
NAROK	4.991	6.655	13.644	29.35	29.68
SAMBURU	1.596	2.002	4.104	28.521	28.75
T.NZOIA	7.597	10.316	21.149	27.92	28.29
KAJIADO	5.868	7.485	15.344	30.16	30.45
W.POKOT	6.510	11.519	23.614	29.63	30.24
TURKANA	0.805	1.115	2.286	26.22	26.52
U.GISHU	3.919	5.173	10.606	28.77	29.07

eters. Those that were estimated without adjusting for net out-migration rates (Table 5.6.4) are considerably higher. On a similar account, the force of mortality is demonstrated by the difference between net reproduction rates and gross reproduction rates, or between the mean ages of mothers at birth. These are listed in Table 5.6.3.

Even though we have accounted for the known demographic components of fertility, mortality and migration, other forms of attrition or accession may exist that affect population in a manner analogous to migration or mortality. "... the age composition of any population at any moment (assuming that age composition and its change are continuous) is completely determined by the rate of increase in the number at each age at a given moment, together with the rate of attrition at each age from each of a number of independently operating factors".(2) For instance, the number of people aged 'a' can be expresed:

$$N(a) = N(O)\, e^{-\int_0^a r(x)dx}\, e^{-\sum_i \int_0^a \mu i(x)dx}\ , \qquad (5.8.1)$$

where r(x) is analogous to any of i attrition factors. If all the other factors were known the rate of attrition for any given factor could be determined. These other factors are not known. It is to be hoped that it is sufficient to correct for migration in the rate of increase at each age so that the Kenyan population - or any other - can be analysed as a closed one. Attrition factors in form of various causes of mortality, or attrition from the married state (divorce) need not be adjusted for in this study since analysis is with respect to the aggregate population. Flaws in the determination of correct growth rates are likely to emanate mainly from incorrect migration rates and reporting errors. The effect of miscellaneous but unidentified attrition and accession factors on growth rates is not known, and is not expected to be significant.

5.9 PERFORMANCE OF THE AGE-SPECIFIC GROWTH RATE TECHNIQUE IN ESTIMATION OF FERTILITY PARAMETERS.

The age-specific growth rate technique analyses any population as a closed one, but instead of a constant growth rate (as in stable populations) the rate of increase varies with respect to age. The rate of increase is a built-in form of attrition determined by a difference in age-cohort size that in turn is dependent on past rates of attrition and accession. The merit of this is that one should be able to obtain the true pattern of fertility events from r(x)'s that include past influances on the age-structure.

The rate of growth in the neighborhood of age zero, 1r0, poses a delicate problem, however. In the equation

$$1 = \int_{\alpha}^{\beta} e^{-\int_0^a r(x)dx} p(a)m(a)\, da,$$

the growth rate at any age and the current net maternity function are formally related but, in reality, causally independent. The growth rate about age zero, unlike at other ages, is dependent on the prevailing net maternity function. "If the net fertility function is changing from year to year because of changes in the rate of childbearing, it is the role of the growth rate in the neighborhood of age zero to be modified in such a way as to ensure that (the equation above) continues to hold".(3)

One flaw in this study is that the growth rate (including both intrinsic and migration rates) about age zero can not be calculated from Kenya's census data. We have taken the risk of assuming 1r0 is reliably approximated by the growth rate of the age cohort aged between one and five years. In turn we hope that the migration rates of these children are identical to that of the age cohort of women aged 15 to 19 years.

Growth rates about age zero are thus a source of analytical error. To illustrate this problem, we calculated total fertility rates by alternatively using migration rates of women aged 20 to 24 to represent 5e0. Total fertility rates thus obtained were in some districts higher by almost one child.

Table 5.6.5 Intercensal TFRs Obtained by the Age-specific Growth Rate Technique by Substituting 5e20 for 5e0.

REGION	TFR	REGION	TFR	REGION	TFR
KENYA	8.422	N.EASTERN	6.993	R.VALLEY	7.437
NAIROBI	4.180	GARISSA	7.511	BARINGO	8.480
CENTRAL	7.664	MANDERA	7.427	MARAKWET	8.689
KIAMBU	7.955	WAJIR	6.882	LAIKIPIA	7.699
KIRINYAGA	9.478	NYANZA	8.065	NAKURU	7.665
MURANGA	8.489	KISII	9.620	KERICHO	9.268
NYANDARUA	10.205	SIAYA	6.654	NANDI	8.676
NYERI	8.788	S.NYANZA	6.018	NAROK	7.185
COAST	4.298	KISUMU	7.415	SAMBURU	6.014
KILIFI	6.589	WESTERN	6.629	T.NZOIA	7.161
KWALE	6.673	KAKAMEGA	8.939	KAJIADO	7.157
LAMU	6.699	BUNGOMA	9.729	W.POKOT	7.048
MOMBASA	4.496	BUSIA	7.416	TURKANA	4.635
TAITA	8.728			U.GISHU	7.610
T.RIVER	7.916				
EASTERN	6.274				
EMBU	8.906				
ISIOLO	7.101				
KITUI	7.946				
MACHAKOS	7.876				
MARSABIT	5.673				
MERU	8.497				

The same problem applies to the estimation of other parameters.

Intercensal birth rates may be more reliably estimated than the other parameters. It may be infered from equation 5.4.1 that estimation of birth rates makes no direct use of reported age distributions. An advantage here is that age-specific growth rates would be unaffected if distortions were proportionate at both censuses.This is likely to be the case as the 1979 census age-sex distribution was 'corrected' by projecting 1969 census fertility and mortality information.(4) The problem of faulty growth rates about age zero still holds, however.

The estimation of the other parameters relies on the net maternity function which may suffer age-related distortions. The 1979 population census anlytical reports recorded over-statement of age among adolescent girls and young women, and over statement of age among young children, resulting in a shortfall of children aged under five years.

Errors affecting age-specific growth rates may be categorised into two major groups.

(1) Differences in coverage completeness between censuses, and

(2) Intercensal changes in the patterns of age misreporting.

The second problem is less serious as patterns of age misreporting are not likely to differ significantly between two consecutive censuses. Furthermore, if these involve only transfers between two adjacent age groups the effect should not be serious because the computational procedure used in this chapter involves cumulation of growth rates to a particular age.

Age-specific growth rates are, however, very sensitive differences in census coverage completeness.(5) Accurate measurements of completeness of census coverage are not available. It is quite possible that the age-specific growth rates upon which the technique fundamentally relies may be distorted by differential coverage.

FOOTNOTES.

1. Central Bureau of Statistics. 1979. Kenya Population Census, 1979, Vol.2. Government Printer. Nairobi. p.56.
2. Preston, S. H. and Coale, A. J. 1982. "Age Structure, Growth Attrition, and Accession: A New Synthesis" in Population Index. No. 48(2). p.221.
3. Preston, S. H. and Coale, A. J. 1982. Ibid. p. 227.
4. Central Bureau of Statistics. 1979. Op cit. p.115.
5. Preston, S. H. and Coale, A. J. 1982. Op cit. p.248.

CHAPTER SIX.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS.

6.1 INTRODUCTION.

The object of this study was to estimate intercensal fertility using various parameters. These were estimated by applying several standard indirect procedures and models of fertility, which were also compared. Although the techniques were devised originally for estimation, they have also been applied in evaluation of data quality. The applicability of the techniques considered in this study in intercensal estimation fundamentally depended on adjustment techniques used to synthesise data drawn from the 1969 and 1979 censuses. Prior to application of P/F ratio methods, Coale-Demeny's formula, Brass -Rachad's formula and the relational Gompertz model we adjusted census data using the additive synthetic adjustment technique. The age-specific growth rate technique is itself an adjustment technique and did not require preliminary adjustment of data.

6.2 SUMMARY AND APPRAISAL OF TECHNIQUES.

6.2.1 ADJUSTMENT TECHNIQUES.

The additive synthetic technique facilitated the estimation of intercensal fertility levels by synthesising a third data set from the 1969 and 1979 censuses. The synthetic data set reflects the effects on a hypothetical cohort of a prolonged exposure to the vital rates in operation during the intercensal period. The age specific growth rate adjustment technique enabled application of a modified concept of stable population. It modified the basic assumption of uniform growth for the whole population to apply only to within specified age groups. The rate of increase at each age (in our case, five-year age groups) is the result of differences in cohort size that is caused by exposure of the hypothetical age cohort to past rates of attrition and entry into the population. This reflected, among other things, the effect of vital rates in operation during the intercensal period.

The two adjustment techniques facilitated the use of information that could be collected reliably, namely both the sexes' age distribution, numbers of children born in the past, numbers of children who have died, and of live births in the twelve months preceeding each census. These data were only indirectly related to the parameters that we estimated. In the case of the additive synthetic technique, the estimates that actually refered to the intercensal period were obtained by applying standard indirect techniques to the adjusted sets of data.

6.2.2 COMPARISON OF STANDARD PROCEDURES ADJUSTED BY THE ADDITIVE SYNTHETIC ADJUSTMENT TECHNIQUE.

The P/F ratio methods discussed in Chapter Two are important indirect procedures that adjusted the level of observed current set of age-specific fertility rates by comparing average parities that these [F(i,s)] implied to those P(i,s)'s that were actualy reported. Although constant fertility for the previous fifteen years or so was originally assumed, hypothetical cohorts average parities, P(i,s), were substituted for the average parities reported by the true cohorts - P(i,1) and P(i,2) - to facilitate estimation for the intercensal period even if fertility had been changing.

Intercensal fertility estimates obtained by the P/F ratio methods were reasonably consistent with fertility levels estimated for the 1969 and 1979 separately. The Coale-Trussell method obtained slightly lower levels and performed less successfully than the Brass method. For Garrissa, Baringo, Kericho, West Pokot and Turkana Districts the total fertility rates obtained by the Coale-Trussell method were clearly not acceptable. In the instance of Garissa District, the total fertility rate of -3.19 and the behaviour of P/F ratios indicated gross error in the basic data.

The Brass P/F ratio method obtained intercensal estimates that varied from the separate estimates for individual censuses by smaller deviations than in the case of the Coale-Trussell method. A trend common to both techniques is that for the majority of districts intercensal levels were higher or lower than estimates obtained for either of the two censuses. The suggestion here was either over-adjustment by the additive synthetic adjustment technique or distortion caused by differential coverage between the two censuses. Generally where fertility rose from 1969 to 1979 the intercensal levels were higher than the latter census'. The reverse was true where fertility declined from 1969 to 1979.

Examination of P/F ratios was instrumental in appraising basic data. The ratios were high and not consistent for younger women whose data are traditionally expected to provide reliable correcting factors. In common with previous researchers we found that better results were obtained by employing the average of P/F ratios for a wider range of ages (in our case, all ages). Clearly data on births reported in the twelve months preceeding each census were not consistent with the data given by the same women regarding children ever born.

The P/F ratio methods would be more robust than, say, those that derive estimates directly from parity increments if the correction factor was from data refering to women aged between twenty and thirty-four only, as omission of children ever born by older women would not affect results. Under reporting by older women was not likely to influence results in most cases. Except for Kenya at national level and a few districts in Rift Valley and Coast Provinces, P(i,s)/F(i,s) ratios did not decline with age as would be expected if older women under reported the number of children ever born. But since the ratios were not constant by age and were far from 1.00 the age pattern and levels implied by hypothetical mean parities and cumulated fertility were not consistent. The tendency of the ratios to rise with age for the majority of districts suggested declining fertility levels in the country.

Although the P/F ratio methods were based on fertility information arrived at internally there is no objective way of judging their success. Their estimates were however reasonable and consistent with those obtained by previous researchers.

(Anker and Knowles, 1982; Mwobobia, 1982; Osiemo, 1986).

Chapter Three examined intercensal fertility estimation based on reported lifetime fertility. The two procedures considered, namely Coale-Demeny's $P3^2/P2$ formula and Brass-Rachad's $P2(P4/P3)^4$ formula estimated total fertility from the average parities of young women and compared these with average parities of women aged over forty-five years.

The former procedure obtained lower and more consistent estimates of total fertility than the latter, and was hence considered more accurate. Based on a sound demographic rationale that was relevant to Kenyan communities, the Coale-Demeny procedure obtained reasonable total fertility rates whose levels were slightly lower than the P/F ratio methods. As with the P/F ratio methods, those districts that experienced a rise in fertility levels from 1969 to 1979 had intercensal levels that were upwardly biased, and vice-versa. Intercensal estimates obtained by the Coale-Demeny procedure were less exaggerated when compared to separate estimates for 1969 and 1979 than in the case of P/F ratio methods.

The Coale-Demeny and Brass-Rachad procedures also provided rough internal evaluation of average parity data. Comparison of average parity of women in their twenties to that of women aged over forty-five years not only showed the Coale-Demeny procedure to be robust but also indicated consistency in parity data for the former women. For the latter women over-reporting of children ever born or exaggeration of age was suggested. The Coale-Demeny procedure indicated under reporting of children ever born by the same women only in six districts.

Although the procedure drew data from a very small age range the final estimates suffered no large deviations from the expected levels, which would be anticipated if there was error in observed information from women in their twenties, or in adjustment over the same age range. In contrast, the Brass-Rachad procedure obtained much higher estimates and had wider deviations. The inclusion of mean parities for 30 to 34 age group in estimation must have introduced errors which affected the perfomance of the procedure.

The relational Gompertz model discussed in Chapter Four, designed for evaluation and adjustment of fertility estimates, was an improved modification of the P/F ratio methods. As a standard procedure it did not necessarily assume that the quality of reporting did not vary with the age of respondents, or that fertility levels had been constant in the recent past. While the P/F ratio methods estimated the pattern of fertility from current births and fitted this pattern to the mean parities for the aggregate child-bearing population, the the model was fitted to both current births and mean parities. For one, the Gompertz procedure separated out distortions contributed by current fertility data from those contributed by parity information, and the use of Zaba's procedure separated the examination of fertility patterns from the examination of fertility levels. Secondly, the model was fitted to current fertility data using z(x) which was based on sectional comparisons of fertility rates. The fitting averaged the current rates, making the estimated total fertility rates for each age group less vulnerable to changes and erratic errors than the P/F corrections. Furthermore, we applied standard fertility rates that were developed by Booth (1979) using a selection of Coale-Trussell models that seemed most appropriate for high fertility populations.

The Gompertz procedure should be more robust than the traditional P/F ratio methods. It yielded reasonable and acceptable total fertility estimates. These showed fertility levels to be about the same as those calculated by the Coale-Demeny formula, and lower than the estimates obtained by the P/F ratio methods. Fitting the model to current fertility data was less successful than fitting it to lifetime fertility data, especially for women aged over forty years. Apart from suggested reporting errors, total fertility rates obtained by fitting the model to F(x) data were too low.

Analysis of intercensal fertility patterns at the national level from a combination mean parities and cumulated fertility rates revealed no substantial effects of reporting errors. For individual censuses, however, a similar analysis indicated omission of children ever born by older women. The effect of any type of error on intercensal patterns must have been obscured by a combination of several types of errors, and/or the use of measures refering to hypothetical cohorts minimised the effect of errors introduced by trends.

6.2.3 THE MERIT OF THE ADDITIVE SYNTHETIC ADJUSTMENT TECHNIQUE IN INTERCENSAL ESTIMATION.

By way of comparison, standard indirect procedures such as the P/F ratio methods did not estimate fertility levels as well as the Coale-Demeny procedure or the Gompertz model due to the presence of trends. The use of current fertility data, which reflected trends, tended to distort estimation of levels (P/F ratio methods) or was in itself not very successful (Gompertz model) in estimating levels. Such biases originated from poor data. Another cause was the simplification of true population experiences and regularisation of data that was necessary for the indirect techniques to function, but which made the procedures not flexible enough in estimating levels in the presence of trends.

The effect of trends was, however, minimised by using measures (mean parities and age-specific fertility rates) that refered to hypothetical cohorts. Adjustment by the additive synthetic technique avoided problems introduced by changing vital rates. By chaining together 1969 and 1979 vital rates, the constructed data set, say f(i,s), reflected the effect on a hypothetical cohort of exposure to similar rates indefinitely.

6.2.4 PROBLEMS ARISING FROM THE USE OF THE ADDITIVE SYNTHETIC ADJUSTMENT TECHNIQUE IN INTERCENSAL ESTIMATION.

The effect of exposing a cohort of women throughout its lifetime to given fertility rates is reflected by their average parity. The difference

$$P(i,2) - P(i,1)$$

gives some indication of the timing of fertility. This is subject to two assumptions:

(1) The cohort of women whose average parity, P(i,2), was recorded at 1979 census was the same cohort whose average parity, P(i,1), was recorded at 1969 census, and

(2) Age, as the variable used to define cohorts, was consistently reported at both censuses.

The women interviewed in the 1979 census may not be exactly the same women interviewed in the 1969 census because daeths and migration. If the women who failed to survive had different fertility from survivors (consider for example birth-related deaths among teen-aged women) then the parity change for the cohort reflected intercensal fertility as well as selective mortality. Also, average parity may have been affected by in- and out-migration of women whose average parity was different from that of the area under consideration.

If age was not consistently reported at both censuses the reported members of an age group at 1979 census did not include all members or only members of that age-cohort reported at 1969 census. Intercensal changes in fertility would be contaminated by the effect of changes in the composition of the cohort. The size and direction of this effect depended on the nature of age-reporting error involved.

The additive synthetic technique required construction synthetic data set by summing up a number of differences between 1969 and 1979 cohort parities. The hypothetical parity distribution thus obtained is usually sensitive to error changes which seem to have been exaggerated. Figures 7.6(a) through

7.6(g) illustrate the magnitude of this exaggeration. (See appendix 3).

In conclusion, whereas using measures refering to hypothetical cohorts minimised the effect of trends on the perfomance of standard indirect techniques in estimation of intercensal levels, the usefulness of such hypothetical cohorts was limited. Indirect estimates that we obtained were reliable, but less so with the P/F ratio methods because of the presence of trends. These included changes in vital rates and the existence of different errors in the two censuses.

6.2.5 APPRAISAL OF THE AGE-SPECIFIC GROWTH RATE TECHNIQUE AGAINST INDIRECT TECHNIQUES ADJUSTED BY THE ADDITIVE SYNTHETIC ADJUSTMENT TECHNIQUE.

The additive synthetic adjustment technique improved the performance of indirect techniques by minimising effects of changing vital rates on estimation of period fertility levels. (P/F ratio methods and fitting Gompertz model to F(x) data. The performance of the Coale-Demeny procedure and of the Gompertz model fitted to P(i) data in the estimation of intercensal levels was greatly enhanced as they suffered no biases introduced by trends.

But as already noted, the additive synthetic adjustment technique failed to adjust

(a) the force of selective mortality and migration on intercensal fertility of a cohort of women.

(b) inconsistency in age reporting at the two censuses. Any variable reflecting intercensal changes in fertility and mortality rates also included the effects of changes in the composition of a cohort.

The age-specific growth rate adjustment tecnique, by comparison, adjusted biases in intercensal estimates arising from effects of changes in the composition of cohorts. The rate of growth within each age group was determined by differences in the age-cohort size that in turn was caused by past rates of attrition and entry into the population. We adjusted the effects of changes in vital rates as well as in migration on growth rates (5rx + 5ex). Subsequently, changes in the age distribution between censuses were, to a good measure, free from both true and erroneous fluctuations.

The disadvantage of the age-specific growth rate adjustment technique was that we relied on the Coale-Demeny (1966) model life tables to determine the level and pattern of mortality. To the extent that there was distinction between the true mortality pattern and the mortality pattern of the model stable population, the age distribution adjusted by the technique lacked some of the general shape of the true population.

While by relying on adjusted growth rates within five-year age groups the technique artificially maintained consistency of age reporting between censuses, the effects of age misreporting on other demographic characteristics (besides the age distribution) such as the number of children ever born, of children dead or recent births were not nullified by simple adjustment of the age distribution. Since we did not know which age groups of women misreported their age and by how much, we could not adjust age classifications of children ever born, children dead or recent births for effects of age misreporting directly. Our recourse was to rely on the use of age-specific growth rates and the Coale-Demeny models to adjust for effects of age misreporting.

Even then, our age-specific growth rates about age zero were not flawless. However, the age-specific growth rate technique produced one of the most accurate set of fertility estimates since it adjusted for forces of mortality, migration and inconsistency in age reporting.

Table 6.2 compares total fertility rates.

Table 6.2 Summary of Total Fertility Rates Adjusted by the Additive Synthetic Adjustment Technique and the Age-specific Growth Rate Technique.

REGION	P/F Methods Brass	Cl-Trssl	2 p3 /p2	4 P2(P4/P3)	Gompertz P(i)	F(x)	A.S.G.R. Technique
KENYA	8.04	7.974	7.078	8.902	7.512	6.599	8.422
NAIROBI	4.34	4.1369	5.630	4.947	4.540	-	3.249
CENTRAL	6.75	7.924	7.774	8.347	7.323	4.816	6.961
KIAMBU	5.95	5.699	7.410	8.691	8.054	5.549	7.288
KIRINYAGA	8.23	7.691	8.003	8.483	7.871	5.395	8.207
MURANGA	6.89	6.292	7.820	7.928	8.810	6.522	8.208
NYANDARUA	7.42	6.947	8.464	8.953	7.512	5.391	8.661
NYERI	6.52	6.0198	7.864	7.906	7.323	4.816	7.651
COAST	7.84	7.617	6.073	8.904	6.862	5.452	4.233
KILIFI	9.09	8.952	6.405	9.907	7.097	6.455	6.741
KWALE	8.10	7.956	6.428	8.743	7.308	5.255	6.997
LAMU	9.70	9.704	6.051	10.751	7.607	6.326	6.156
MOMBASA	5.07	5.068	5.080	5.466	4.743	3.823	3.863
TAITA	8.68	8.680	7.419	9.288	8.326	6.118	9.092
T.RIVER	9.86	9.861	6.209	11.904	8.608	6.224	7.555
NYANZA	8.11	7.765	7.683	9.803	7.766	5.556	7.820
KISII	9.64	9.028	9.417	10.479	9.314	6.217	8.846
SIAYA	7.73	6.993	6.885	9.419	7.105	5.549	6.766
S.NYANZA	7.34	7.747	7.262	9.707	7.584	5.451	7.199
KISUMU	8.06	7.592	6.733	8.838	6.865	5.957	6.099
WESTERN	8.05	6.626	7.499	10.088	8.054	5.180	6.509
KAKAMEGA	7.58	6.075	7.489	9.804	7.585	3.518	9.130
BUNGOMA	8.87	7.843	7.957	10.186	8.872	6.607	9.183
BUSIA	7.33	7.234	7.031	10.547	7.329	5.647	6.858
N.EASTERN	4.60	5.272	6.977	7.098	6.785	3.491	6.815
GARISSA	-1.47	-3.189	6.948	8.418	7.431	2.802	7.591
MANDERA	8.32	8.324	6.461	6.646	6.424	4.911	7.252
WAJIR	5.87	5.397	7.201	6.379	6.334	3.305	6.472
EASTERN	6.91	6.350	7.167	8.878	7.248	4.785	6.202
EMBU	7.47	6.796	7.781	8.589	7.469	5.177	8.452
ISIOLO	9.45	9.398	5.695	7.930	5.912	8.524	6.411
KITUI	5.14	5.547	7.237	9.967	7.562	5.517	7.457
MACHAKOS	7.29	6.656	7.320	10.167	7.786	4.886	8.471
MARSABIT	5.53	4.957	4.995	5.175	4.985	4.903	5.278
MERU	7.27	6.752	7.185	7.493	6.699	5.271	7.998
R.VALLEY	9.19	8.927	6.959	8.327	8.044	6.612	7.116
BARINGO	8.10	11.71	7.393	10.006	8.101	8.149	8.210
MARAKWET	4.59	7.503	6.827	3.190	4.598	2.568	8.653
LAIKIPIA	6.87	7.873	6.914	9.310	7.909	5.979	7.251
NAKURU	6.73	9.222	4.614	8.546	6.737	-	6.929
KERICHO	8.63	10.048	7.532	11.519	8.631	-	8.405
NANDI	8.62	9.016	7.097	10.223	8.618	6.906	8.046
NAROK	7.84	8.782	6.713	7.665	7.843	7.216	7.193
SAMBURU	7.45	8.882	6.104	6.915	7.457	8.627	6.456
T.NZOIA	7.35	5.739	6.927	7.151	7.354	4.269	6.988
KAJIADO	6.87	5.785	6.746	8.326	6.874	-	6.491
W.POKOT	7.63	10.563	6.473	9.163	7.629	6.819	7.372
TURKANA	6.79	11.6597	5.506	7.874	6.793	2.390	4.795
U.GISHU	7.54	8.753	7.171	8.944	7.540	6.613	7.135

6.3 CONCLUSIONS.

From the foregoing study we made the following conclusions:

(1) Indirect techniques that estimate intercensal fertility levels in the presence of trends like the Brass and the Coale-Trussell P/F ratio methods or fitting the relational Gompertz model to current fertility data do not perform well enough.

(2) Indirect techniques that rely on lifetime fertility data such as Coale-Demeny's $P3^2/P2$ formula are more reliable than those that combine both parity and current fertility data in estimation of intercensal fertility.

(3) Fitting the relational Gompertz model to parity data estimates intercensal fertility more reliably than fitting the model to current fertility data.

(4) Fitting the relational Gompertz model parity data is more robust in intercensal fertility estimation than the traditional P/F ratio methods.

(5) Coale-Demeny's $P3^2/P2$ formula estimates intercensal fertility more reliably than Brass-Rachad's $P2(P4/P3)^4$ formula.

(6) Hypothetical cohort parities for the 1969 to 1979 intercensal period are consistent for women in their twenties, but not for other ages.

(7) The 1969 and 1979 data on births reported in the twelve months preceeding each census were not consistent with data reported by the same women regarding the number of children ever born.

(8) The use of measures refering to hypothetical cohorts minimise effects of intercensal changes in vital rates and error patterns on estimated fertility levels.

(9) Hypothetical cohort average parities and age-specific fertility rates that are adjusted by the additive synthetic adjustment technique are sensitive to changes in error between 1969 and 1979 censuses.

(10) The age-specific growth rate adjustment technique is reliable in intercensal estimation only if changes in the composition of cohorts from one census to another are adequately adjusted for.

(11) The effect of migration on changes in the composition of cohorts has considerable effect on the performance of the age-specific growth rate adjusment technique in estimation of intercensal fertility.

(12) The most reliable fertility rates for the 1969 to 1979 intercensal period were estimated by the formula $P3^2/P2$, the age-specific growth rate adjustment technique and by fitting the relational Gompertz model to parity data.

6.4 RECOMMENDATIONS.

6.4.1 POLICY RECOMMENDATIONS.

(1) Techniques that use indirect information are useful where vital registration data are inadequate. Such indirect information can be collected reliably using surveys. We recommend that frequent surveys be carried out to augument

the regular census operations. These surveys should be structured in a manner that brings out true fertility trends, something that may be difficult in censuses.

(2) Census data on fertility in Kenya are not as accurate, consistent and coherent as required for accurate estimation of parameters. We recommend that census data be adjusted using parts or features of survey data sets that may be more reliable. Particular attention should be paid to age-related reporting errors in fertility data.

(3) We further recommend the use of post-enumeration surveys for purposes of verification and appraisal of data.

6.4.2 RECOMMENDATIONS FOR FURTHER RESEARCH.

We recommend further research work in the following study areas:

(1) The extent to which trends affect indirect estimation of intercensal fertility levels. This is called for in view of the inadequacy of indirect methods that estimate fertility levels in the presence of trends.

(2) Since the additive synthetic adjustment technique does not adjust the force of selective mortality and migration on intercensal fertility of a cohort of women, and inconsistency in age reporting in two censuses, estimated intercensal changes in fertility rates are contaminated by the effects of changes in the composition of a cohort. There is need to study the effect of selective mortality and migration on the performance of indirect techniques in estimation of intercensal fertility.

(3) There is also need to study simulation procedures that correct age distributions for differential census coverage completeness, and inconsistency in age reporting.

(4) Through simulation, projection or estimation, total fertility rates that represent replacement level fertility in Kenya should be determined.

(5) A casual observation of results in Chapter Five seemed to indicate a relationship between the mean ages at birth and religious or cultural norms associated with fertility. For example, districts with considerable Muslim compositions like Kilifi, Mombasa, Lamu and Tana River, have older mean ages at birth. Also, most districts in Eastern Province which are likely to share socio-cultural norms have older mean ages at birth. It should be worthwhile to study the relationship between the mean length of the female generation and religious or socio-cultural norns regarding nuptial unions, post-partum amenorhea, and fertility levels in general.

(6) Effects of exogenous attrition and accession factors other than mortality and migration on the performance of the age-specific growth rate technique in estimation of fertility should also be examined.

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APPENDIX 1: LIFE TABLE CONSTRUCTION.

A life table can be constructed from estimates of child mortality. The Coale-Trussell model of mortality requires information on children ever born (CEB) and children surviv- (CS) or children dead (CD) classified by mothers' age, and the female population (FPOP) classified by five year age groups. The probability of dying before attaining age x is given by:

q(x) = K(i) D(i)

for x = 1,2,3,4.5,10,15,and 20

and i = 1,2,3,4,5,6,and 7 which represents the age groups 15-19, 20-24,...,45-49.

K(i) =a(i) +b(i)P(i)/P(2) +c(i)P(2)/P(3)

where a(i), b(i) and c(i) are Trussell's coefficients for estimating child mortality.

P(i) is the average parity for age group i

and D(i) is the proportion of children dead for age group i.

That is,

$$P(i) = \frac{(CEB)}{(FPOP)} \quad \text{for age group } i$$

and

$$D(i) = \frac{(ACD)}{(CEB)} \quad \text{for age group } i,$$

where the average number of children dead (ACD) is calculated:

ACD(i) = CD/FPOP

It will be recalled that for intercensal estimation of fertility data sets from 1969 and 1979 censuses were synthesised to form a third set, P(i,s), for a hypothetical cohort. A similar procedure (See Chapter Two) is applied here.

Calculation of intercensal average parity and proportions of children dead, the subsequent development of a life table is demonstrated below using data for Kenya at national level.

Table 6.1 Calculation of Proportions of Children Dead For Hypothetical Cohorts, Kenya.

AGE GROUP	1969 P(i,1)	1979 P(i,2)	P(i,s)	1969 ACD(i,1)	1979 ACD(i,2)	ACD(i,s)	D(i,s)
15-19	0.35	0.320578	0.320578	0.044695	0.037231	0.037231	0.116137
20-24	1.88	1.854308	1.854308	0.275420	0.231302	0.231302	0.124737
25-29	3.65	3.652108	3.622686	0.634005	0.515147	0.507683	0.140139
30-34	5.11	5.388082	5.362390	1.033753	0.893554	1.124856	0.209767
35-39	6.00	6.470268	6.442954	1.385400	1.194057	1.067735	0.165721
40-44	6.44	7.021534	7.273924	1.693076	1.526678	1.617781	0.222408
45-49	6.69	7.173540	7.616494	2.031084	1.816020	1.067735	0.140187

The probability of dying, q(x), refered to in this section is for both sexes. To obtain the q(x) for females or males the sex ratio of 105 males per 100 females was used. Thus, the q(x) for females which we require is obtained by dividing the q(x) for both sexes by 1.05.

Table 6.2 Calculation of the Probability of Dying Before Age x.

index (i)	a(i,s)	b(i,s)	c(i,s)	D(i,s)	k(i,s)	q(x)	l(x)
1	1.1119	-2.9287	0.8507	0.116137	1.172557	0.136177	0.863823
2	1.239	-0.6865	-0.27545	0.124737	1.036828	0.12933	0.87067
3	1.1884	0.0421	-0.5156	0.140139	0.958144	0.134273	0.865727
4	1.2046	0.3037	-0.5656	0.158406	0.980768	0.155359	0.844641
5	1.2586	0.4236	-0.5898	0.165721	1.037128	0.171873	0.828127
6	1.224	0.4222	-0.5456	0.184544	1.022513	0.188698	0.811302
7	1.1772	0.3486	-0.4624	0.196725	1.005409	0.197789	0.802211

Mortality levels for females were estimated from the Coale-Demeny life tables using l(2), l(3) and l(5) calculated by subtracting q(x)'s above from one. To estimate the mortality levels values obtained from these were interpolated from model ones. Mortality levels corresponding to l(2), l(3) and l(5) are 14.000, 14.83306 and 14.78196, respectively. Their arithmetic average is 14.53835, taken to be the average level of mortality.

Table 6.3 Interpolation of Mortality Levels.

	LOWER	UPPER	LOWER	UPPER		
l(2)	14	15	0.86841	0.88329	14.00000	14.53835
l(3)	14	15	0.85139	0.86860	14.83306	
l(5)	14	15	0.82886	0.84904	14.78201	
l(10)						
l(15)						
l(20)						

Likewise, the probability of surviving to age x, p(x) was interpolated from model levels 14 and 15 using the level obtained above.

Table 6.4
Interpolation of the Probability of Surviving to age x

Age	14	15	p(x)
1	0.89613	0.90699	0.901976
5	0.82886	0.84904	0.839723
10	0.80185	0.82525	0.814442
15	0.78736	0.8122	0.800732
20	0.77059	0.79668	0.784635
25	0.74896	0.77646	0.763764
30	0.72599	0.75495	0.74158
35	0.70143	0.73191	0.717838
40	0.67449	0.70651	0.691727
45	0.64404	0.67745	0.662026
50	0.61014	0.64466	0.628723
55	0.56857	0.60372	0.587493
60	0.51779	0.55332	0.536917
65	0.45153	0.48651	0.470361
70	0.36666	0.39967	0.38443
75+	0.26441	0.29308	0.279844

The mortality levels obtained were used to construct a life table. Each P(x) was multiplied by the radix l(o) to obtain the number of survivors at age x i.e. l(x).

Table 6.5 Life Table for Synthetic Cohorts, Kenya.

GROUP	nPx	nQx	l(x)	nDx	nLx	Tx	ex
0-1	0.901976	0.098024	100000	9802.4	93432.39	5134391.	51.34391
1-4	0.930981	0.069018	90197.6	6225.29	344305.8	5040958.	55.88794
5-9	0.969898	0.030101	83972.31	2527.66	413542.4	4696652.	55.93097
10-14	0.983159	0.016840	81444.65	1371.55	403794.3	4283110.	52.58921
15-19	0.979897	0.020102	80073.1	1609.7	396341.2	3879316.	48.44718
20-24	0.973365	0.026634	78463.4	2089.8	387092.5	3482974.	44.38980
25-29	0.970988	0.029011	76373.6	2215.7	376328.7	3095882.	40.53602
30-34	0.967984	0.032015	74157.9	2374.2	364854	2719553.	36.67247
35-39	0.963625	0.036374	71783.7	2611.1	352390.7	2354699.	32.80270
40-44	0.957062	0.042937	69172.6	2970.1	338437.7	2002308.	28.94655
45-49	0.949695	0.050304	66202.5	3330.3	322686.7	1663871.	25.13305
50-54	0.934422	0.065577	62872.2	4123.03	304053.4	1341184.	21.33191
55-59	0.913912	0.086087	58749.17	5057.54	281102	1037130.	17.65354
60-64	0.876040	0.123959	53691.63	6655.61	251819.1	756028.8	14.08094
65-69	0.817309	0.182690	47036.02	8593.05	213697.4	504209.7	10.71965
70-74	0.727944	0.272055	38442.97	10458.63	166068.2	290512.2	7.556967
75+	0	1	27984.34	27984.34	124443.9	124443.9	4.446915

The remaining life table functions were computed as follows:

(i) nPx, the probability of surviving between age (x) and (x+n) was given by the formula:-

$$nPx = l(x+n)/l(x)$$

(ii) nqx, the probability of dying between age (x) and (x+n) was given by the formula:

$$nqx = 1 - nPx.$$

(iii) ndx, the number of persons dying between age (x) and (x+n) was given by:

$$ndx = l(x) - l(x+n).$$

(iv) nLx, the persons years lived between age (x) and (x+n) where:

$$1Lo = 0.3*l(o) + 0.71*l(1)$$

$$4L1 = 1.3*l(1) + 2.7*l(5)$$

$$5L5 = 2.5*l(5) + l(10)$$

&L(75) = l(75)*log[l(75)]

where & represents infinity.

(v) T(x), the total population from age (x), was given by:

$T(x) = T(x+n) + nLx$

(vi) e(x), the expectation of life at age (x), was given by:

$e(x) = T(x)/l(x)$.

APPENDIX 2: DERIVATION OF NET MIGRATION RATES.

The proportion of persons aged "a" is given by:

$$c(a) = b*p(a)*\exp\left(-\int_o^a [r(x)+e(x)]dx\right) \qquad (6.2.1)$$

where,

$e(x)$ is the net out-migration rate.

$c(a)$ and "b" can be replaced by $N(a)/N$ and $N(o)/N$ respectively.

The formula therefore becomes:

$$N(a) = N(o)*p(a)*\exp\left(-\int_o^a [r(x)+e(x)]dx\right)$$

$$\frac{N(a)}{N(o)*p(a)} = \exp\left(-\int_o^a [r(x)+e(x)]dx\right)$$

$$\ln \frac{N(a)}{N(o)*p(a)} = -\int_o^a [r(x)+e(x)]dx$$

$$= -\int_o^a r(x)dx - \int_o^a e(x)dx$$

Therefore,

$$\int_o^a e(x)dx = -\ln \frac{N(a)}{N(o)*p(a)} - \int_o^a r(x)dx$$

This implies,

$$\int_o^{a+5} e(x)dx = -\ln \frac{N(a+5)}{N(o)*p(a+5)} - \int_o^{a+5} r(x)dx$$

$$\int_o^{a+5} e(x)dx - \int_o^a e(x)dx = -\ln \frac{N(a+5)}{N(o)*p(a+5)} + \ln \frac{N(a)}{N(o)*p(a)}$$

$$= -\int_o^{a+5} r(x)dx + \int_o^a r(x)dx$$

Therefore,

$$\int_a^{a+5} e(x)dx = \ln \frac{N(a)}{N(a+5)} * \frac{p(a+5)}{p(a)} - \int_0^{a+5} r(x)dx$$

$$5 * {}_5e_a = \ln \frac{N(a)}{N(a+5)} * \frac{p(a+5)}{p(a)} - 5 * {}_5r_a \qquad (6.2.1\ b)$$

$${}_5e_a = \frac{-1}{5}\ln\left[\frac{N(a)}{N(a+5)} * \frac{p(a+5)}{p(a)}\right]^{-1} - {}_5r_a$$

i.e.

$${}_5e_a = \frac{-1}{5}\ln\left[\frac{N(a+5)}{N(a)} * \frac{p(a)}{p(a+5)}\right] - {}_5r_a \qquad (6.2.1\ c)$$

Fig. 7.4(a) THE LEVEL AND PATTERN OF FERTILITY : COAST PROVINCE

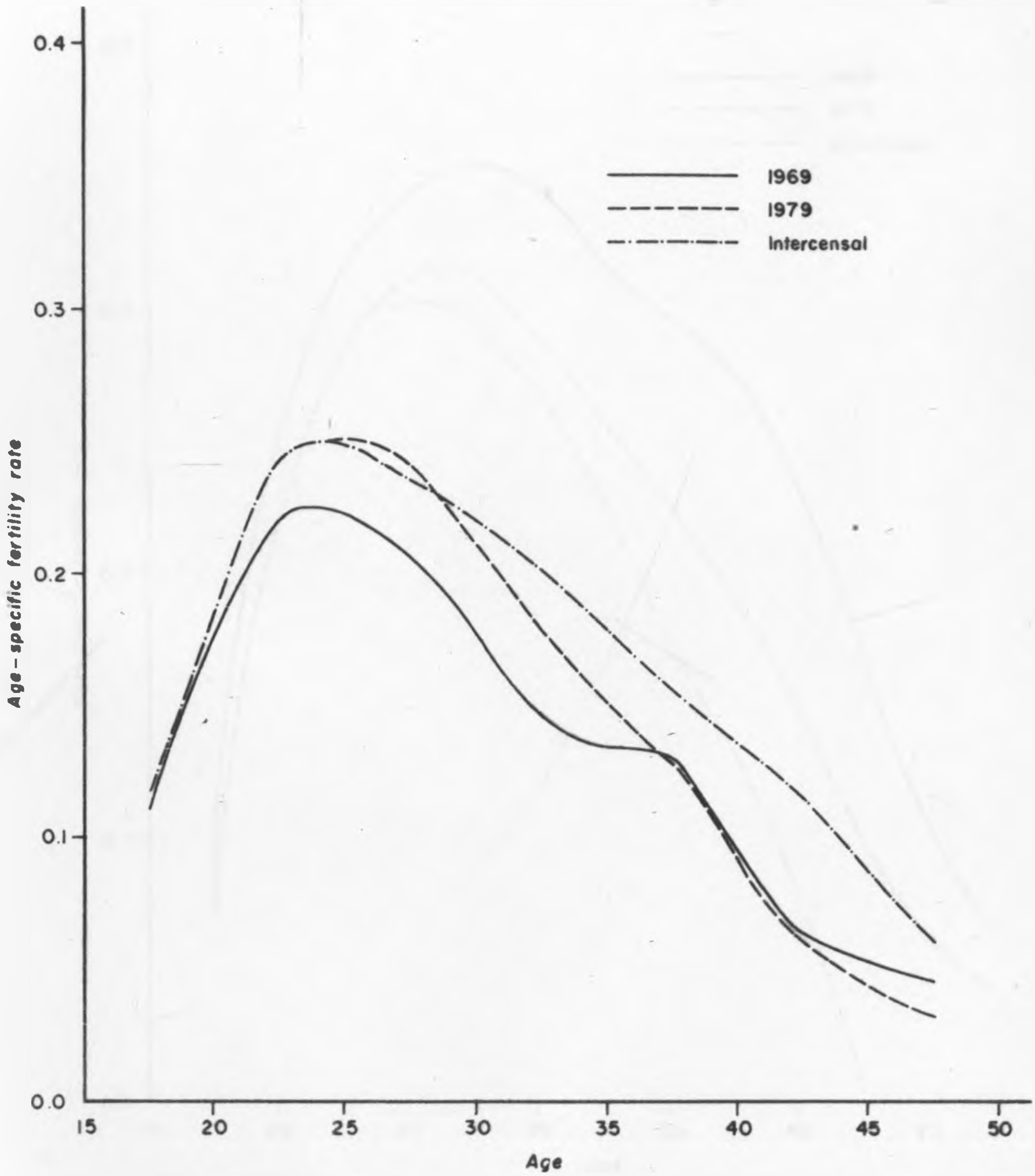

Fig. 7.4(b) THE LEVEL AND PATTERN OF FERTILITY : CENTRAL PROVINCE

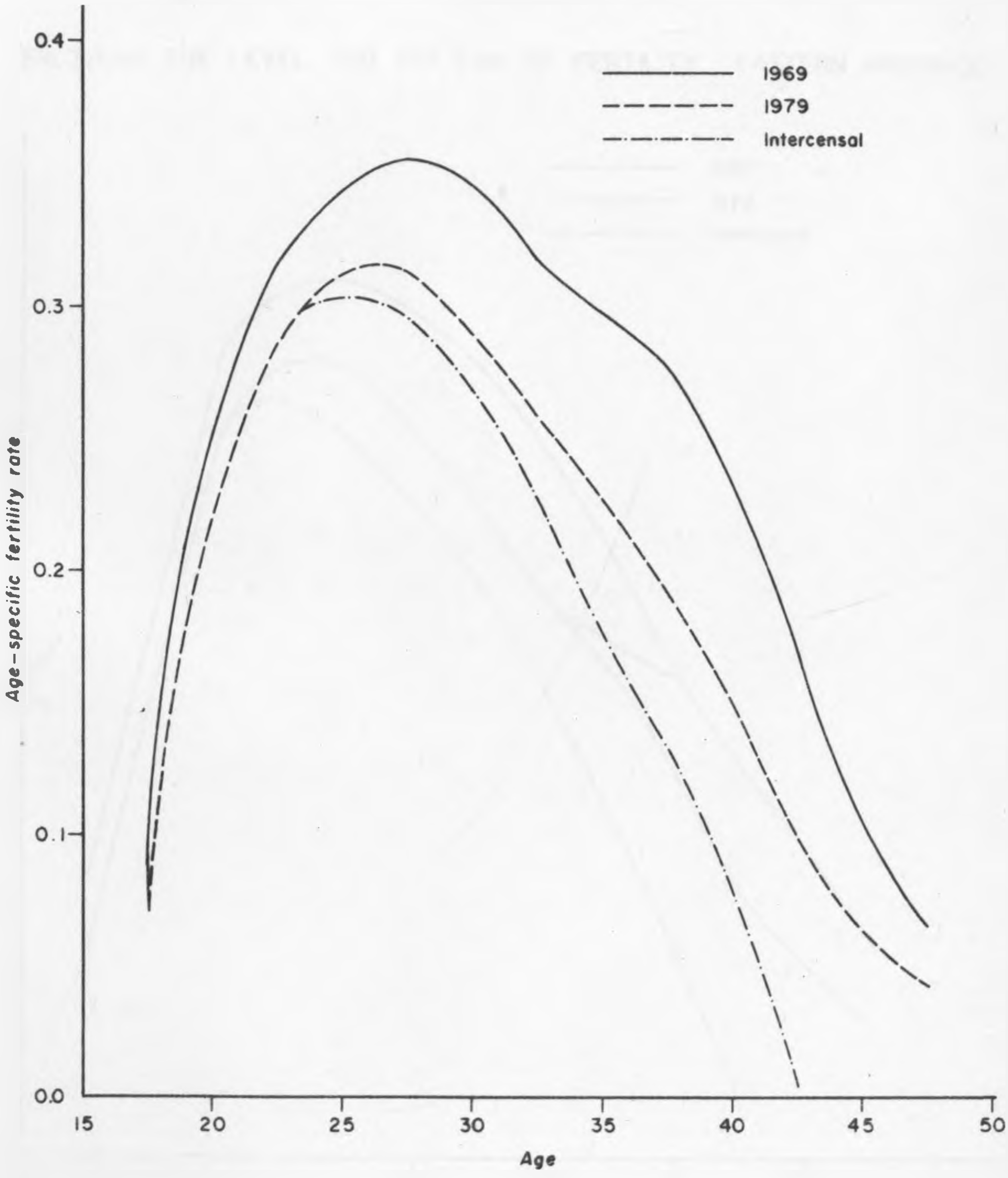

Fig. 7.4 (c) THE LEVEL AND PATTERN OF FERTILITY : EASTERN PROVINCE

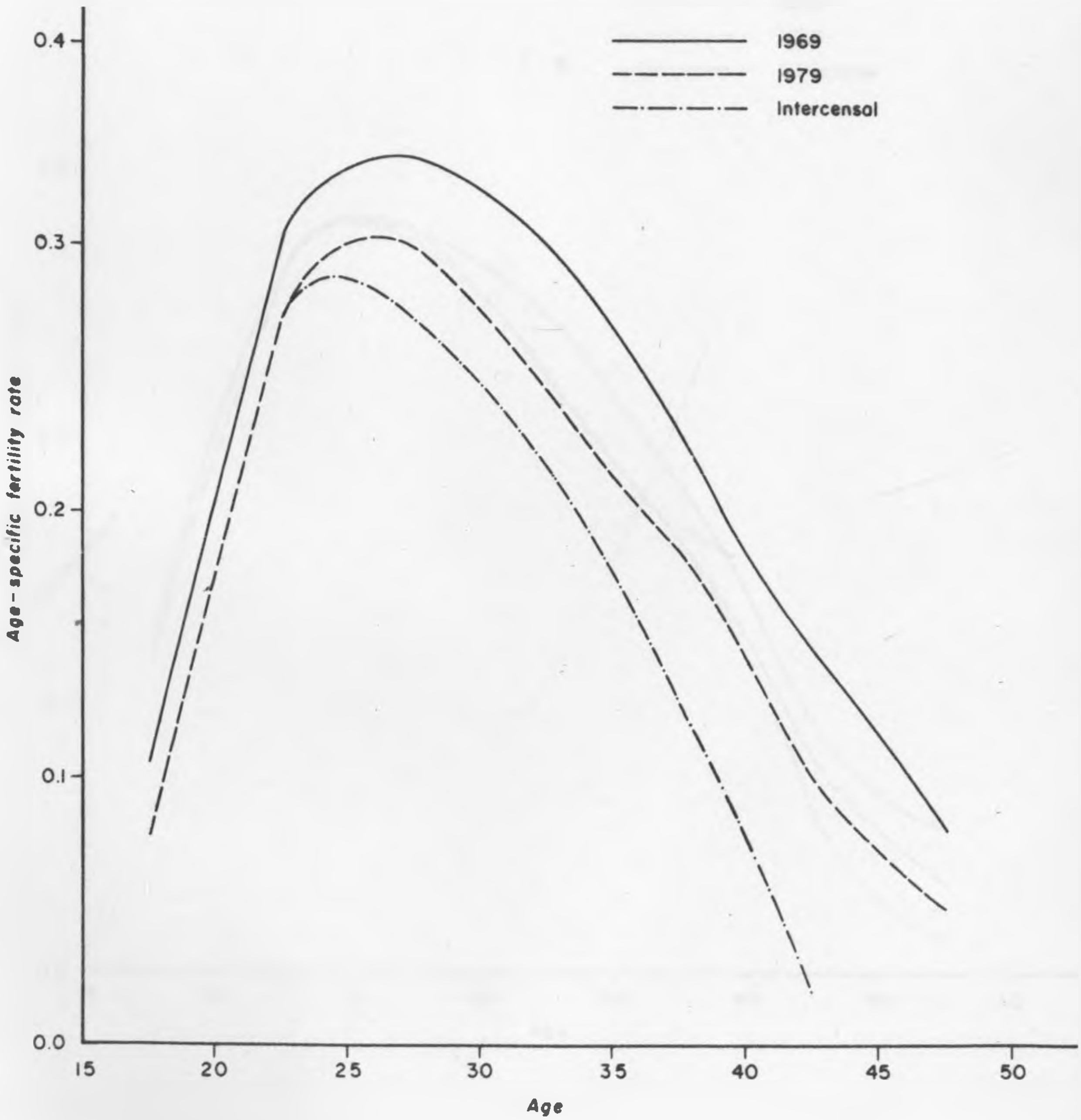

Fig. 7.4 (d) THE LEVEL AND PATTERN OF FERTILITY : NYANZA PROVINCE

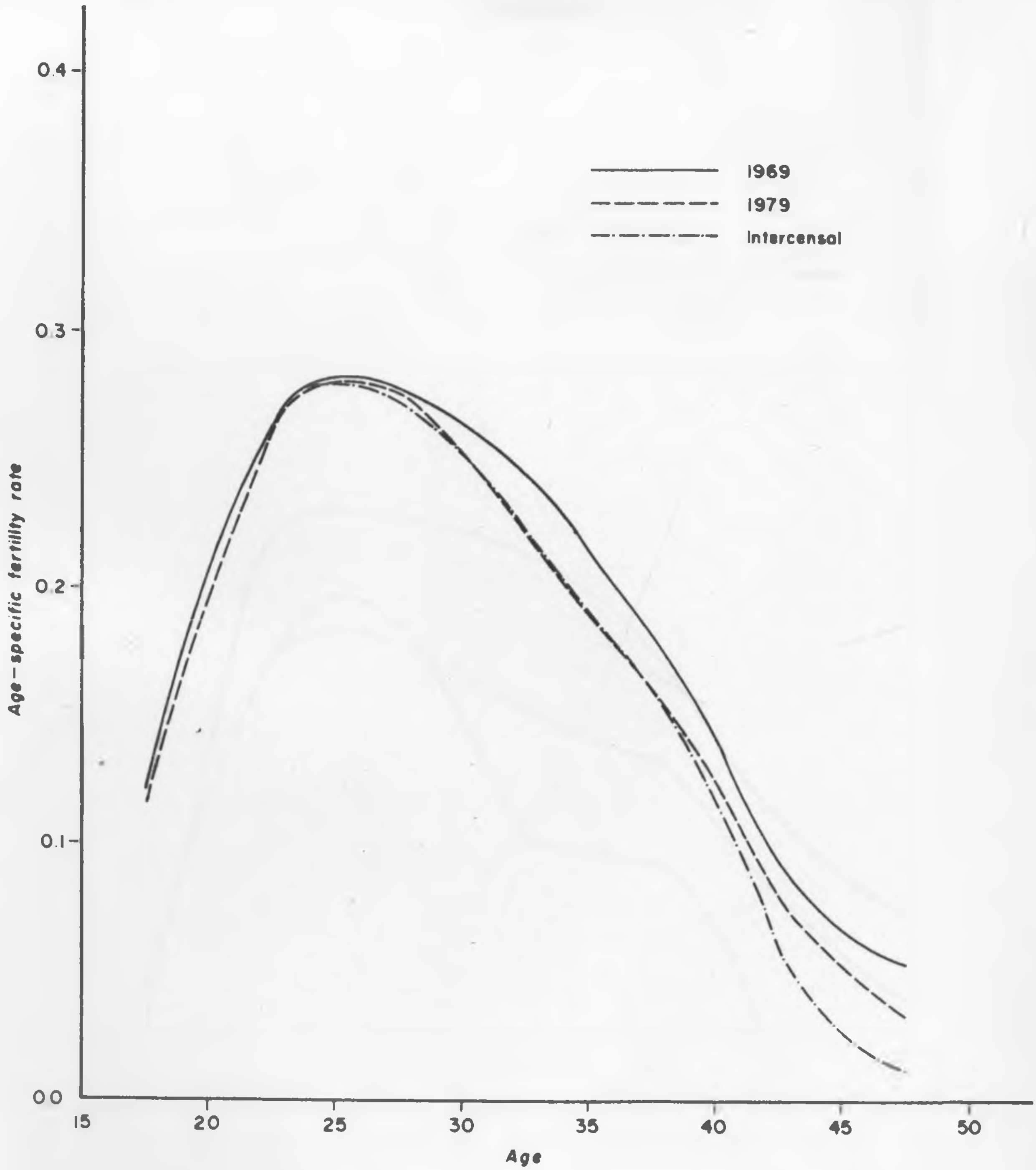

Fig. 7.4 (a) THE LEVEL AND PATTERN OF FERTILITY : NORTH-EASTERN PROVINCE

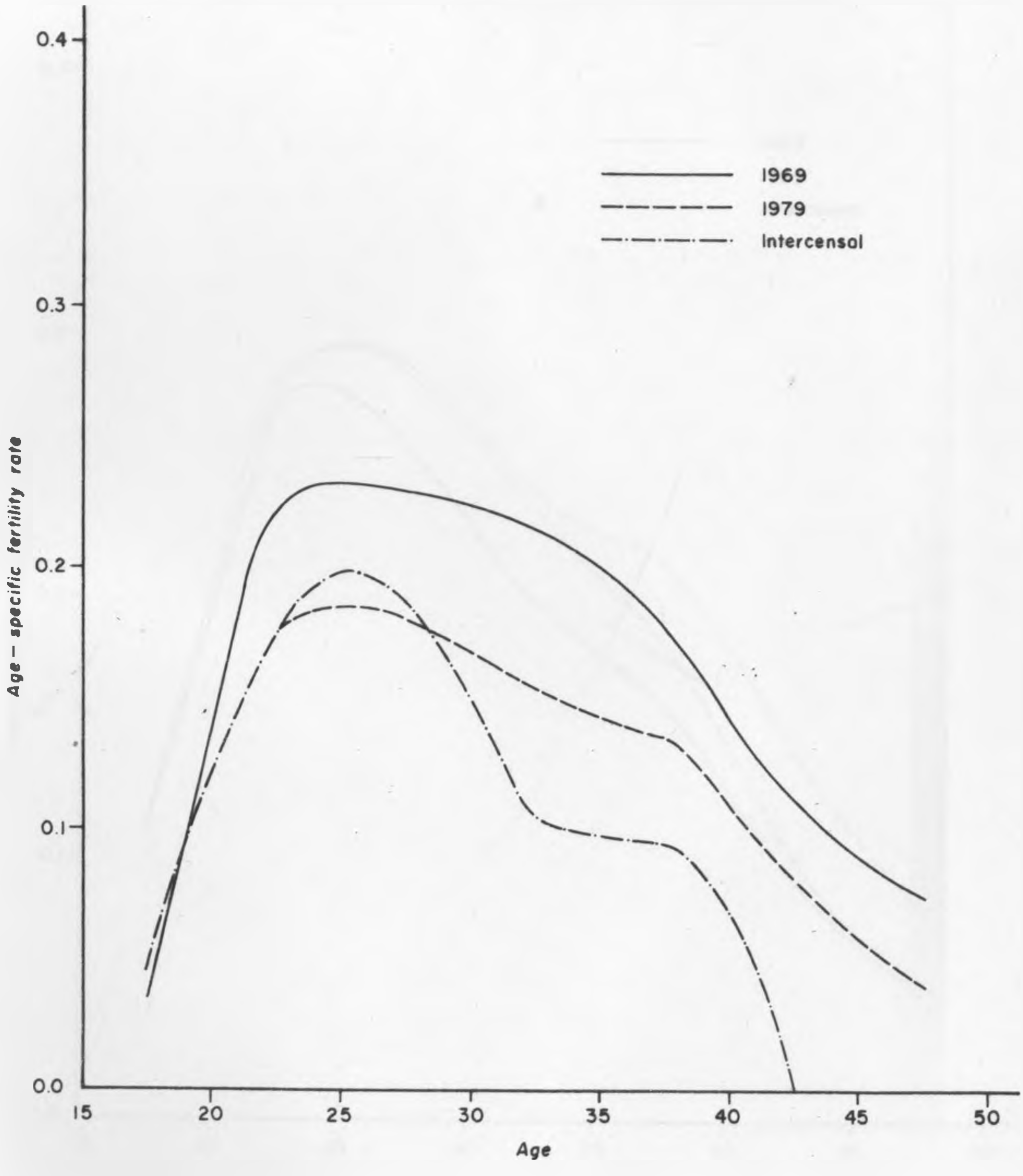

Fig. 7.4 (f) THE LEVEL AND PATTERN OF FERTILITY : RIFT VALLEY PROVINCE

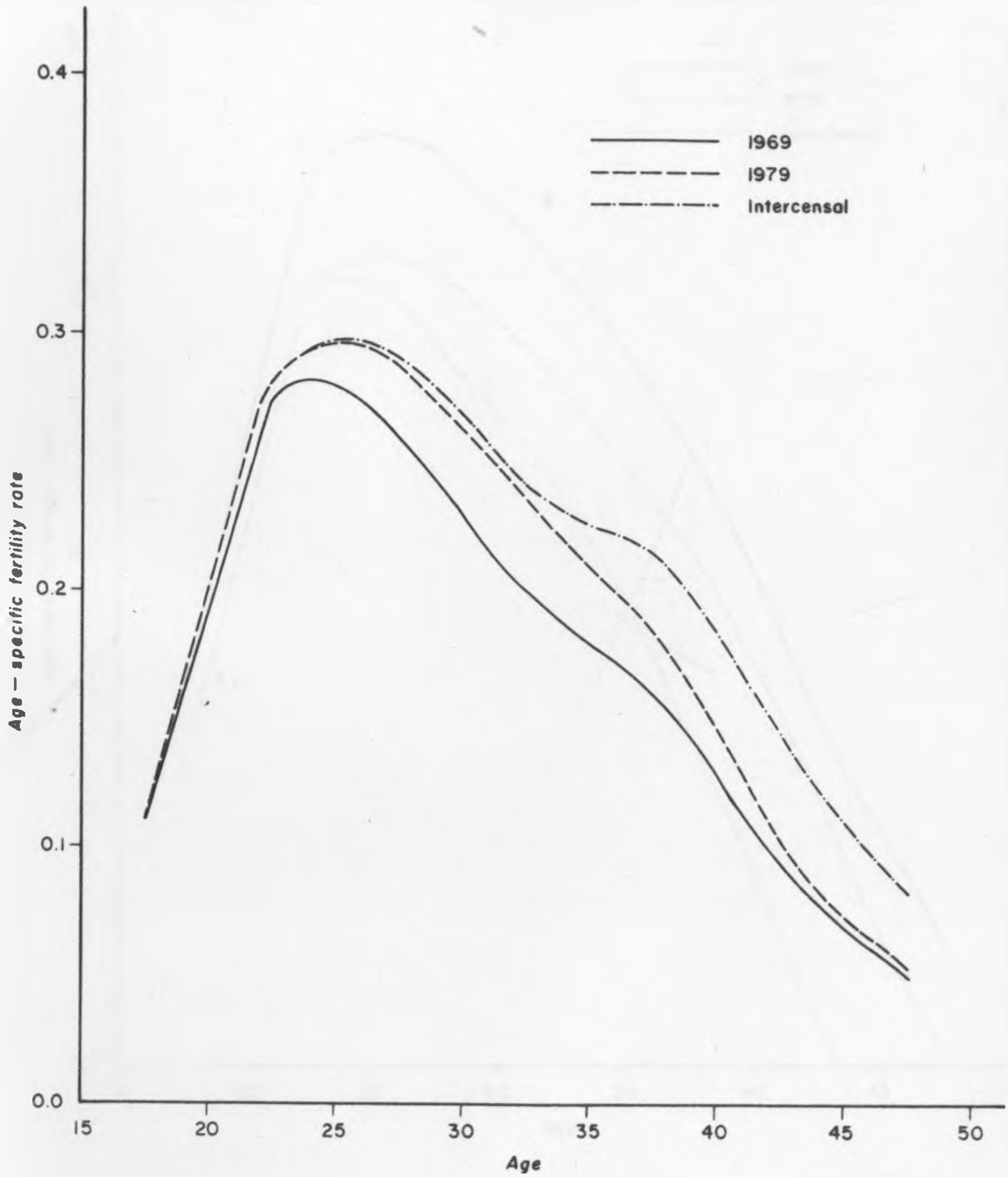

Fig. 7.4 (g) THE LEVEL AND PATTERN OF FERTILITY : WESTERN PROVINCE