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Development Team

Principal Investigator	Prof. Anup Kumar Kapoor Department of Anthropology, University of Delhi
Paper Coordinator	Prof. Gautam K. Kshatriya Department of Anthropology, University of Delhi
Content Writer	Ms. Shalini Singh & Prof. Gautam K. Kshatriya Department of Anthropology, University of Delhi
Content Reviewer	Dr. Satwanti Kapoor (Retd Professor) Department of Anthropology, University of Delhi

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LEARNING OBJECTIVE

- To understand and utilize a variety of commonly used data to estimate fertility
- To discuss the various measures of fertility estimation

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1. Introduction to tools of demographic estimation

Tools for Demographic Estimation is an outcome of a project, funded by the United Nations Population Fund (UNFPA) and the International Union for the Scientific Study of Population (IUSSP) in order to bring out together in one place in a user-friendly style of key methods used by demographers everywhere to measure the various demographic parameters derived from limited and defective data. The idea took its origin at a joint IUSSP/UNFPA meeting on 'Applied and Technical Demographic Training in Developing Countries' held in The Hague in March 2009. Changing global population led to revision of agenda adopted by International Conference on Population and Development held in Cairo in 1994. Associated with this, the cohort of demographers who had been trained in the classical methods and techniques was ageing rapidly and few younger demographers were being trained in either the science or the craft of demographic estimation from limited and defective data. In a perfect world, data would always be complete, accurate, current, pertinent, and unambiguous. Data is assumed to be complete, accurate, current, unambiguous and pertinent but in reality, it is generally flawed on some or all of these dimensions". The task of evaluating and assessing data is an essential part of identifying the nature, direction, magnitude and likely significance of these flaws. While the primary point at which data evaluation and assessment takes place is immediately after the data have been processed, data evaluation and assessment are recursive activities – at each analytical stage, the user of demographic data should consider the results produced with a sceptical eye, alert to possible indications of error or bias introduced by the data into the results.

In most settings and in the long term, fertility is the single most important determinant of population dynamics and growth. This section gives an overview of the classes of methods available for the measurement of fertility.

2. Sources of Data

The information of demographic data is the vital registration system as for the most part, the registration of births in developing countries is incomplete due to lack in incentives by parents. This results and late registration of births (for example, when the child attains school-going age) may mean that there is a delay of several years before all the survivors of the cohort born in a given year have their births registered.

The second valid source of data is a census which seeks summary information about lifetime fertility, the number of children ever born, and still alive and fertility is narrowly defined for period of time before the census. The current fertility rates are estimated by the demographers. The scope for internal validation and cross checking of the answers is limited due to inter related questions asked in the census. Moreover the data collected in censuses commonly suffer from two errors. Firstly, the data on lifetime fertility increases poorly with an increasing age of the mother where the omissions is for those children who have died or who are no longer living with the mother. Secondly, the data on recent fertility tends to be systematically underreported by all women. Possibly over-enumeration of recent births takes place which is, occasioned by misunderstandings related to the reference period used. Thus methods used to estimate fertility take into consideration these errors into account. Adding to the profile of questions asked on summary of fertility, survey often enquires question about birth history of mothers. Such histories ask about child's date of birth, vital status and death of child in any. The effort expended on such detailed data collection frequently limits the sample sizes of the investigations. In such cases, variability in the estimated rates, and the inability to investigate finely-grained spatial or other differentials in fertility are an inherent weakness of this approach.

3. Types of Fertility Estimation

In order to estimate fertility the methods incorporated depends on the type of data and the fertility estimation involves direct and indirect methods.

3.1) Direct Estimation of fertility Rate.

There are three possible approaches to measure fertility directly. The first approach uses data from a vital registration system in accordance with estimates of the population by age and sex. The calculation of fertility is straight forward when the data for the numerator and denominator are complete and unbiased, and also when the denominator appropriately reflects the population exposed to risk of giving birth by age.

The second approach uses the full birth history data collected in a survey and the various validation checks that can be built into the survey instrument. Detailed information on the birth of each child, as well as the mother's age, is obtained. Accordingly, the age of the mother at the birth of each child can be determined exactly, and births and exposure-to-risk can be allocated to particular calendar years or other time periods.

The third approach uses the summary fertility measures routinely collected in censuses to estimate recent fertility. Of course, if the data suffer from the common problem of under-reporting of recent births in censuses, the resulting estimates of fertility will be too low.

3.1.1) Direct estimation of fertility from survey data containing birth histories

The direct estimation of fertility (age-specific, and total) from survey data containing birth histories is relatively straightforward. If the data are carefully collected with a validated instrument (such as that used by the Demographic and Health Surveys), they can provide reliable and accurate estimates of fertility. However, distortions also frequently occur in birth history data, especially in relation to the shifting of births to more distant years to avoid additional questions on, for example, child health or anthropometry (Cleland 1996). These problems have again been highlighted recently by Schoumaker (2010, 2011). Displacement and omission of births might cause fertility (particularly in the period three to five years before the survey) to be underestimated.

Two approaches can be used to estimate fertility directly from data containing a detailed birth history.

1) Data produced from the official reports often used by District household surveys, which produces an estimate covering the entire three-year period before the survey. A three-year period estimate is used frequently to avoid undesirable fluctuations arising from the small number of annual births in the DHS). Disadvantages of data used from the official documents are.

- The survey carried out over an extended period becomes impossible to locate the measure of fertility precisely in time.
- The calculation of fertility rates is more complex by referring to the survey date and by working in five-year age groups and three-year periods of calendar time.

3.1.2. <u>Cohort-period fertility rates</u>

The availability of detailed demographic and birth history data typically collected in demographic surveys (examples being the World Fertility Surveys conducted in the 1970s, and the ongoing programme of Demographic and Health Surveys conducted by ORC Macro) has meant that – in general – direct measures of fertility estimation are to be preferred over indirect methods. Nevertheless, extensions of indirect methods to situations where there is more data can provide not only corroborating evidence to support the results derived directly, but also provide important insights into the quality of the birth history data collected.

One such extension is to apply the same logic as the Brass *P*/*F* ratio method to the birth histories, allowing a detailed investigation of the fertility data by age, period and cohort. The method yields period estimates of total fertility (TF) for either the five-year period or the two five-year periods preceding collection of the data. The method also permits the identification of common errors in the data.

3.2) Indirect estimation

Direct estimation of fertility is used to derive indirect estimates of fertility. It is derived from the summary information on recent births, these recent births is misreported in censuses which uses information on the lifetime fertility of younger women reported in the same census to adjust the direct estimates. The earliest method of indirect estimation of fertility is the Brass *P*/*F* method, set out by Brass (1964). The method was made understood in in *Manual X* (UN Population Division 1983), along with a number of variants for extending the method depending on exactly what data are available. The relational Gompertz method is a further refinement to the*P*/*F* method. The extensions to the *P*/*F* method can be included under such situations where:

- The lifetime and current fertility data from more than one census are available where the analyst seeks to estimate fertility for the intercensal period .
- Censuses or surveys conducted either in past five or ten years gives only data on lifetime fertility making it necessary to estimate fertility from the increments in parities.
- Data on lifetime fertility and on births in intercensal period are available from two censuses example a vital registration system. This approach is based on the the comparison of mean number of births which got registered by a cohort of women having average parity of the same cohort. It also allows one to assess the completeness of the data on registered births.

3.2.1 The Brass P/F ratio

The foundation of the indirect estimation of fertility rate has its origin from the assumption that fertility remains constant for an extended period of time and also the cohort and period measures of fertility remains identical. Moreover in conditions of constant fertility, the cumulated fertility of a cohort of women will be the same as the cumulated fertility up to that same age in any given period.

Assuming that there are no appreciable mortality differentials by the fertility of mother, the surviving women have materially different levels of childbearing from deceased women; the average parity in the stated cohort is same as the cumulated fertility of a cohort of women up to concerned age. (This assumption is not very important as even if there are differentials in the fertility of living and deceased women, in most populations the magnitude of female mortality in the reproductive ages is very small and the effect of differential survival will therefore be small.)

Brass defined *P* to be the average parity or cumulated lifetime fertility of a cohort of women up to a given age, and *F* to be closely related to the cumulated current (period) fertility up to that same age. The *P*/*F* ratio method expresses these two quantities in relation to each other in the form of a ratio for each age group.

The derivation of *F* is stated complicated for two reasons. Firstly, any comparison of cohort and period fertility deals with the probable shifting of the data on recent fertility brought about by the question being based on the age of the mother at the time of the inquiry rather than her age at the time of her most recent birth. Secondly, while the cumulation of period fertility will reflect the fertility experience of all women till that, the average parities typically calculated reflect women in 5-year age groups and hence reflects the average parity of women aged at the midpoint of that age group. The method formulated by Brass addresses both these aspects.

The P/F ratio will be equal to 1 in every age group if fertility has been constant in a population for an extended period of time and the data is free from any kind of error. In situations where the fertility has been falling, the cumulated current fertility will be less than current fertility. In this case (in the absence of errors in the data) the *P*/*F* ratio would depart from unity systematically with increasing age of mother. It is expected that the *P*/*F* ratio is fairly close to unity at the youngest ages because even by women's mid-twenties one would not expect significant deviation of cumulated period fertility from cumulated lifetime cohort fertility as most of the births to women in that cohort would have happened fairly recently. The *P*/*F* ratio derived from women in the age group of 20-24 years at the time of a survey is held to be the most reliable indicator of the quality of the fertility data. Upon supposition, the average parities of younger women are usually fairly accurately reported, at least relative to those of older women.

It is this characteristic pattern of departure from unity with age of mother that forms the basis for many diagnostic investigations into the nature and quality of data drawn from questions based on recent and lifetime fertility.

Diagnostic based on the P/F ratio.

The data is never free from error and imagining the hypothetical pattern of departure of the *P*/*F* ratio from unity is confounded and obfuscated by underlying errors in the data.

The evaluation of recent fertility data and evaluation of lifetime fertility data come across two types of error typically affecting the data. The first error is that reports on lifetime fertility i.e., cumulated cohort fertility – becomes inaccurate with age of the respondent, were older women tend to under-report their lifetime fertility. Errors of this type will therefore tend to affect the numerator of the *P*/*F* ratio, particularly at the older ages and the ratio will tend to be closer to unity than it might truly be.

Women tend to under report recent births regardless of their age and this is the second type of error reported. Errors of this type will result in somewhat lower fertility than anticipated resulting into an inflated *P*/*F* ratio.

The *P*/*F* ratio method corrects the second problem by applying the *P*/*F* ratio to younger women to the directly observed fertility schedule as a scaling factor.

3.2.1)The Relational Gompertz method

The more improved and versatile version of the Brass P/F ratio method is the relational Gompertz model. It uses the same input data is used as a precursor by further making the same assumptions about errors that affect fertility data. The comparison of lifetime and period fertility lies at the heart of the method and does not require an assumption that fertility has been constant in the past.

Methods using parity increments and indirect methods make use of data from vital registration system. The estimation of cohort-period fertility rates is derived from survey data relies on the logic of the *P*/*F* ratio method to shed light on longer-term trends and dynamics in fertility.

The relational Gompertz method is a refinement to the method that seeks to estimate age-specific and total fertility by determining the shape of the fertility schedule from data on recent births reported in censuses or surveys while determining its level from the reported average parities of younger women.

In producing estimates of age-specific and total fertility, the method seeks to correct the errors commonly found in fertility data associated with too few or too many births taking place in the in the reference period, and it also includes the under-reporting of lifetime fertility and errors of age reporting among older women. The method relies on a useful property of a (cumulated) Gompertz distribution,

$$G(x) = \exp(a.\exp(bx))$$

which is sigmoidal (i.e. S-shaped), but also has an associated hazard function that is right-skewed and which therefore captures fairly well both the pattern of average parities of women by age and their cumulated fertility. The form of $G(x)$ implies that a double-negative log transform of proportional cumulated fertilities or average parities approximates a straight line for most of the age range. The double-log transform,

$$Y(x)=-\ln(-\ln(G(x)))$$

is termed a *gompit* and has a close analogue in the logit transform frequently used in mortality analysis. Brass, however, found that a much closer linear fit could be obtained by a relational model that expresses the gompits of an observed series of fertility data as a linear function of the gompits of a defined standard fertility schedule. In other words,

$$Y(x)=\alpha+\beta Ys(x)$$

where

$Ys(x)$

is the gompit of the standard fertility schedule. Evidently, if $\alpha = 0$ and $\beta = 1$, the fertility schedule will be identical to the standard fertility schedule. Alpha (α) represents the extent to which the age location of childbearing in the population differs from that of the standard (negative values imply an older distribution of ages at childbearing than in the standard), while beta (β) is a measure the spread of the fertility distribution (values greater than 1 imply a narrower distribution).

3.3) Further analysis of fertility

Finally, there are several other methods that may shed light on fertility trends and dynamics.

By using the census data, one can calculate both conventional and projected parity progression ratios. These measures indicate the propensity of women in a population to bear further children contingent on the number of children that they have already borne. Projected parity progression ratios highlights the possible future evolution of parity progression for younger women, taking into account current fertility and the women's childbearing history to date. P/F ratios can also be calculated from the cohort period fertility rate. These rates provide information on trends in fertility and also on the quality of the birth history data. Thirdly, a method exists for estimating fertility measures based on reverse survival of the enumerated population of children and adults.

3.3.1) **Parity Progression Ratio**

A thought of childbearing is often taken by starting a family or adding a new member to the family. Looking at the proportions of mothers who reach a given parity or birth order, there is an increase in their parity by at least one more child.

Birth order information can be easily obtained from two basic census questions: on women's completed parity and on births in the past year. By the help of first question one can disaggregate the births in the past year by birth order. Further examination of fertility data by parity through the use of parity progression ratios and its projected equivalents gives additional information on childbearing trends which can be used to assess changes in the parity distribution of fertility.

This section describes the procedure for calculating parity distributions and parity progression ratios for women who have reached the end of childbearing. The derivation of parity progression ratios to forecast the eventual distribution of younger women by the parities is expected to attain when they reach the end of childbearing.

The idea of calculating projected parity progression ratios proposed by Brass (1985) is less widely known and focuses on the calculation of quantities, although conventional parity progression ratios is required as a part of the process.

A parity progression ratio (PPR) is the proportion of women who progress from one parity to the next. PPRs can be calculated for both cohorts of women defined either by age or marriage. Usually age cohorts of women are calculated from the parity distribution of a particular age group of women. For cohorts of women that have finished childbearing, these measures are fixed. For cohorts that are still in the childbearing ages, the measures changes as the increasing numbers of women move to higher parities. The measures derived from younger women thus suffer from both censoring and selection effects as women predisposed to having more children faster will be disproportionately represented in age-parity combinations before the end of childbearing. This means that comparison of the PPRs of younger and older women is misleading.

Brass (1985) describes a technique for projecting PPRs to the end of women's reproductive years that enables one to use the parity data on younger women. The advantage is that it may respond to different factors, so that changes in particular PPRs may provide insight into the processes of fertility change going on in the population. The parity-specific fertility limitation is readily measured by parity progression ratios. PPRs may also be less affected than more common fertility metrics by some types of data error (e.g. reference period errors). The calculation of first birth rates, carried out in the construction of projected PPRs, can also provide an indication of data quality and fertility change.

The calculation of PPRs for cohorts having completed fertility is straightforward. The comparison of successive cohorts can give information on trends in fertility, a more reliable conclusions can be drawn if PPRs for the same cohorts can be compared across more than one census. For younger women, a more elaborate procedure is required in collecting information on more recent fertility trends. These rates are used to project the expected parity distribution if the younger women experiences the age-order specific fertility rates (AOSFRs) until the end of childbearing. This parity distribution is used to calculate projected PPRs, which can be used to infer changes in fertility that are implicit in women's childbearing histories to date combined with the current AOSFRs. Errors in the AOSFRs results from under-reporting which tends to cancel out when they are used to project PPRs, with the exception of progression from nulliparity to the first birth.

Summary

- The idea to estimate fertility took its origin at a joint IUSSP/UNFPA meeting on 'Applied and Technical Demographic Training in Developing Countries' held in The Hague in March 2009. The task assessing data is an essential part of identifying the nature, direction, magnitude and likely significance of these flaws. While the primary point at which data evaluation and assessment takes place is immediately after the data have been processed, data evaluation and assessment are recursive activities – at each analytical stage, the user of demographic data should consider the results produced with a sceptical eye, alert to possible indications of error or bias introduced by the data into the results.

- The information of demographic data is the vital registration system and census which seeks summary information about lifetime fertility, the number of children ever born, and still alive and fertility is narrowly defined for period of time before the census. Moreover the data collected in censuses commonly suffer from two errors. Firstly, the data on lifetime fertility increases poorly with an increasing age of the mother where the omissions is for those children who have died or who are no longer living with the mother. Secondly, the data on recent fertility tends to be systematically underreported by all women.
- In order to estimate fertility the methods incorporated depends on the type of data and the fertility estimation involves direct and indirect methods.
- The direct estimate of fertility rate uses three approaches to measure fertility. The first approach uses the data from vital registration system. The second approach uses the full birth history data collected in a survey while the third approach uses the summary fertility measure which routinely collects censuses to estimate fertility.
- The indirect estimates of fertility is used to derive from the summary information on recent births, these recent births is misreported in censuses which uses information on the lifetime fertility of younger women reported in the same census to adjust the direct estimates. The earliest method of indirect estimation of fertility is the Brass *P*/*F* method, set out by Brass (1964).
- The evaluation of recent fertility data and evaluation of lifetime fertility data come across two types of error typically affecting the data. The first error is that reports on lifetime fertility i.e.,

cumulated cohort fertility – becomes inaccurate with age of the respondent, were older women tend to under-report their lifetime fertility. Errors of this type will therefore tend to affect the numerator of the *P*/*F* ratio, particularly at the older ages and the ratio will tend to be closer to unity than it might truly be.

- The more improved and versatile version of the Brass P/F ratio method is the relational Gompertz model. It uses the same input data is used as a precursor by further making the same assumptions about errors that affect fertility data. The comparison of lifetime and period fertility lies at the heart of the method and does not require an assumption that fertility has been constant in the past.