Demographic Measurement: General Issues and Measures of Fertility

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Abstract

The article explains the rationale for demographic measures and the principles of their construction. The difference between crude and specific rates is outlined. The main indicators used in the demographic analysis of fertility, including measures of both level and timing, are defined and set out in tabular form. Synthetic cohort indicators of fertility routinely used to summarize sets of period rates are described, and their advantages and disadvantages discussed. The arguments for and against tempo adjusted fertility indicators are outlined.

Introduction

Demographic measures are designed to quantify the level, timing, and distribution of demographic phenomena. Their purpose is to allow comparison across time and space, and between subpopulations. The need for measures arises particularly because the frequency of demographic events and states varies substantially by age; and because populations vary in size and composition with respect to age and other factors influencing the frequency of events and states. Measures may be crude – events per 1000 population, taking no account of population composition – or specific by one or more factors. Rates specific by individual attributes – age, marital status, urban/rural residence – are generally preferable to crude rates. Specific rates may be used to describe e.g., the age profile of demographic event rates, or may be summarized into a standardized single-figure index – such as a total fertility rate (TFR) or period life expectancy – using several forms of standardization.

General Overview

Demographic analysis employs measures of events, states, attributes, and cumulative experience. Classically, a core demographic activity consists in estimating the frequency of vital events, births and deaths, and of related events – migration, marriage and divorce, and, in more recent times, the formation and dissolution of coresidential unions. Other events studied in demography include conception, pregnancy, spontaneous and induced abortion, the use of contraception, leaving the parental home, household formation and dissolution, family changes such as transition to and from lone parenthood, and widow(er) hood. States of demographic interest include marital status, whether legal or *de facto*, type of family or household to which individuals belong, enrolment in education or training, migrant status, and so on. The classic attributes of demographic interest are age and sex, along with ethnicity, country of birth, and socioeconomic characteristics such as educational attainment and social class. Cumulative experience is examined using proportions of ever having experienced an event such as marriage, or estimates of the average number of a specified event experienced in a lifetime, or by a specific age, for example, the mean number of births by a particular age.

Events can be thought of as changes in state and, correspondingly, states can be considered to result from the occurrence and nonoccurrence of events. For example, the event of first marriage changes a person's marital status from single to married, and a person who has married and has not dissolved their marriage is currently married. In addition, the concepts of 'cumulative experience' and 'state' are to some extent interchangeable, for example, a woman who has had n live births (cumulative experience) is said to be of parity n (state) (the term *parity* relates to *women*). Measures of cumulative experience that do not refer to individual states are also used in demography, and these will be considered presently. The current entry does not cover methods of collecting and classifying demographic data, but is concerned with the use of data once it has been collected and processed, ready for analysis.

Demography is concerned in general with aggregate phenomena at the population level, where populations vary from global to local in extent. The units whose events and states are aggregated can be individuals, couples, families, or households. Some demographic measures are, however, strictly aggregate in type. These include the population growth rate, population density per unit area, or population dependency ratios, all of which are meaningful at the aggregate level only. Demographic measures focus on level, timing, and distribution: the frequency of events or prevalence of states (level), the age at or time between events (timing), and distributional aspects such as age structure or the geographical distribution of a population.

The need for demographic rates and other measures is readily stated. Counts of population or events are of demographic interest, particularly in an applied context, and are frequently the key input or output in a policy context. But absolute numbers, whether population size or numbers of vital events, are not sufficient for most analytical purposes. Population analysis is conducted in terms of the underlying phenomena – mortality, fertility, migration, and so on – that determine population change. For example, population projections are usually carried out by the component method, applying assumptions about fertility, mortality, and migration rates, rather than by extrapolating births, deaths, or population numbers. Rates, proportions, and other indices are required also for comparative purposes, whether tracking time-trends or making comparisons between (sub)populations. Spatially and temporally, populations vary in size and also in structure, and so measures that abstract from size and structure are required to compare the demographic metabolism, so to speak, of different populations.

Demographic rates and measures are numerous. The variety stems both from the widely varying forms in which data are available and from the nature of the phenomena themselves. Data may come from vital registration systems, from population registers, from censuses and surveys, from parish registers, and other historical sources; or from administrative records. These sources may differ in the kinds of information recorded, in questions asked, and in details published. Fertility is the area in which measures are probably most numerous, a result of the complexity of the phenomenon: births are repeatable events, they can occur to women inside and outside of marital or cohabiting unions, their order in a birth history can be of significance, and they can be associated with several dimensions of personal time – age, union duration, duration since previous birth, and so on. (The term order relates to births. 'Order' is the order of a birth in a woman's fertility history. 'Parity' is the number of births a woman has already had. First births (births of order 1) occur to childless women, i.e., women of parity 0. Second births (births of order 2) occur to women who have had one birth previously, i.e., women of parity 1, etc. It is incorrect in English to refer to a 'parity 1 birth,' though such mistaken usage can be found in the literature.)

Rates, Probabilities, Proportions, and Ratios

A demographic rate expresses the number of events occurring relative to person years at risk of the event in a defined population for a specified time and place. It may be expressed per person year, per 1000 person years, per 100 000 person years at risk, and so on. The denominator, person years at risk or person years lived, is often estimated by means of the mid-year population or by the average of two end-year population figures, each of these being an approximation to the average population during the year. Francophone demography has specific terms to distinguish between two types of rates. In type 1 rates, the denominator is confined to those who are at risk of the event represented in the numerator (i.e., those who have not yet experienced the event but who could do so in principle). In type 2 rates, no such restriction is applied: the denominator may include people who have already experienced the event. Type 1 rates are known in English as occurrence-exposure rates. There is no specific term in general use in English for type 2 rates, though they are occasionally referred to as incidence rates or accumulation rates. A probability is the likelihood that an individual will experience an event. It is estimated by the number of events occurring during a defined period or at a particular age, to a specified group divided by the numbers of individuals present at the start of the period or age. A proportion is defined in the usual way, as the number with a given attribute at a given time point divided by the total population in question at that time. Finally, demographic measures also take the form of ratios, for example, the sex ratio at birth is the ratio of the numbers of male to female births. Ratios generally refer to aggregates, although anthropometric measurements in ratio form relating to individuals are also found in the medical demographic literature.

Crude Rates and Degree of Specificity

Demographic measures vary in their level of detail. The simplest are crude rates, expressed as the number of events per 1000 (or other multiple) of the total population, without any further specificity. The two most common are the crude birth rate (CBR) – the number of births per 1000 population in a year – and the crude death rate – the number of deaths per 1000 population in a year. They give basic information but do not allow refined analysis. Crude rates are of value in setting out the basic demographic parameters of a population and are used for descriptive purposes, particularly when the data needed for more detailed measures are either unavailable or unreliable.

Demographic rates and other measures are influenced by the composition of the population in respect of any factor by which the frequency of the phenomenon under study varies. Most importantly, crude rates are influenced by the age structure of a population, because of the association between age and demographic event rates, and also by sex composition, since demographic event rates usually vary by sex. Accordingly, specific rates may be calculated by placing conditions on the numerator or the denominator, or on both. Specificity may be introduced for one or more factors. For example, age-specific rates may be influenced by composition in respect of marital status, duration in a particular state, parity (number of children already born to a woman), urban/rural residence, and so on. So, the analyst might choose to calculate rates specific for a number of dimensions. For some purposes, variation according to specific factors may itself be the focus of interest. In other contexts, variation with respect to one factor (e.g., age) is taken as given and is not the subject of study. If so, the analyst will wish to remove the compositional effect from the comparison to be made. Traditionally, one of two procedures is used to remove the influence of such (nuisance) factors. Rates may be standardized for the factors concerned or may be disaggregated progressively so as to arrive at rates specific for internally homogeneous groups. Standardization may be through the conventional direct or indirect methods or by calculating a synthetic indicator of some kind (see Section More Complex Indicators below).

Both procedures have disadvantages. Standardization, whether by the conventional direct or indirect methods, or by constructing synthetic indicators, is well known to be valid only where there are no interactions between the factors for which the standardization is carried out, or when there are no interactions between them and the categories, populations, etc. to be compared. Since such interactions are often found, straightforward standardization is inappropriate in many instances. Progressive disaggregation of rates has the disadvantage of producing potentially large numbers of rates that are not readily summarized and perhaps not readily interpretable. Modern methods of model fitting can in many instances provide a more general and rigorous solution to the routine need for standardization in demographic analysis, and can offer a considerable advance on the progressive disaggregation approach. Hoem (1987) and his predecessors have shown that indirect standardization can be seen as a first step in an iterative estimation procedure for intensity regression based on a multiplicative hazard model.

Measures of Fertility

Basic Measures

Level of Fertility

The definition of the most common fertility measures is set out in Table 1. All of them may be calculated either on a calendar

Table 1 Selected measures of the level of fertility

Measure and time reference[a]	*Definition*[b]	*Notes*[c,d]
Crude birth rate (CBR) Period; cohort version also possible but rare	$\frac{B}{P} \times 1000$	$B =$ number of births $P =$ total person-years lived
General fertility rate[e] (GFR) Period; cohort	$\frac{B}{\sum_{15}^{49} W_x} \times 1000$	$W_x =$ number of woman years lived at age x or in age group x
Age-specific fertility rate (ASFR) Period; cohort	$F_x = \frac{B_x}{W_x} \times 1000$	$B_x =$ births to women aged x or in age group x $W_x =$ woman years lived at age x or in age group x
Total fertility rate[e] (TFR) Period; cohort	$\sum_{15}^{49} F_x$	F_x is the age-specific fertility rate defined above. When rates are for 5-year age groups, the sum is multiplied by 5.
Age-specific marital fertility rate Period; cohort	$\frac{B_{x,m}}{W_{x,m}} \times 1000$	$B_{x,\ m} =$ births to married women at age x or in age group x $W_{x,\ m} =$ woman years lived while married and at age x or in age group x
Age-specific non-marital fertility rate Period; cohort	$\frac{B_{x,u}}{W_{x,u}} \times 1000$	$B_{x,\ u} =$ births to unmarried women aged x or in age group x $W_{x,\ u} =$ woman years lived while unmarried at age x or in age group x
Proportion of births that are non-marital[f] Period; cohort	$\frac{B_u}{B} \times k$	$B_u =$ births to unmarried women during a year or period. The multiplier k may be 100 or 1000. The indicator may also be specific for age.
Age-parity specific fertility rate (type 1 rate) Period; cohort	$\frac{B_{x,i}}{W_{x,i-1}} \times 1000$	$B_{x,\ i} =$ births of order i to women aged x or in age group x $W_{x,\ i-1} =$ woman years lived while of parity i–1 and aged x or in age group x
Age-order specific fertility rate (type 2 rate) Period; cohort	$F_{x,i} = \frac{B_{x,i}}{W_x} \times 1000$	
Parity progression ratio Cohort; period version differs: see text	$a_i = \frac{\sum_{j=i+1}^{j=m} N_j}{\sum_{j=i}^{j=m} N_j}$	*$a_i =$ parity progression of order $i =$ probability of progressing from i-th to $i+1$-th birth* $N_j =$ number of women who have j births m = maximum number of births occurring
Gross reproduction rate[e] (GRR) Period; cohort	$\sum_{15}^{49} F_x^f$	F_x^f is The age-specific rate of female births. The sum is multiplied by 5 if 5-year age groups are used.
Net reproduction rate[e] (NRR) Period; cohort	$\sum_{15}^{49} F_x^f L_x^f$	L_x^f is The average number of person-years aged x in the stationary female life table with specified mortality, with a radix of 1.

[a]All measures given here relate either to a calendar year, time period, or cohort. For clarity, subscripts denoting the time reference are omitted, as most of the measures can be specified in either period or cohort form.
[b]The measures defined in female terms here can be defined analogously for men, but the male versions are rarely used. While summation is to 44 or 49 in a female index, summation could extend to later ages in male indices.
[c]In the specification of demographic rates, person-years lived, whether overall, or at a particular age or in a given state, is the true denominator. Where the rate relates to a year or period, events and person-years lived are those occurring during the year or period in question, at age x, where specified. A cohort rate is based on events experienced and person-years lived by the cohort concerned, at age x, where specified. Person years lived are normally estimated by the mid-year population.
[d]Throughout the table, age x denotes age x in completed years or, equivalently, age x at last birthday.
[e]When summation is over the reproductive ages, the lower limit of the summation is usually 15, but may also be 10, and the upper limit may be 44 rather than 49.
[f]This indicator was formerly known as the illegitimacy ratio.

period or on a cohort basis, though a CBR for a cohort is rarely seen. The article assumes throughout that period or cohort, data on births and population estimates are available. Where this is not the case, indirect methods for estimating population fertility parameters are available (*see* Demographic Techniques: Indirect Estimation).

The CBR is widely used in cross-national comparison, particularly since it requires relatively simple data – an estimate of total births and of total population. The general fertility rate is more specific, and restricts the denominator to those at risk of experiencing a birth, that is, women of childbearing age, usually 15–44 years or 15–49 years. Age-specific fertility rates introduce a further level of detail by age and are key indicators – they reveal both the level and the pattern of childbearing by age and are also the basis for calculating the total fertility rate, a widely used summary indicator described below. Age-specific fertility rates may be disaggregated further – by marital status, by duration of partnership or marriage, in place of or jointly with age, and by order of birth.

Fertility rates that are specific by order of birth are more precise and for many purposes more useful than the more widely available age-specific fertility rates. They are more informative about the nature of change through time because time-trends often vary by order of birth, particularly in modern contracepting populations or where the use of contraception is on the increase. Birth rates by order can be either type 1 or type 2 rates (see Section Rates, Probabilities, Proportion, and Ratios above). A type 1 (or occurrence-exposure) rate is more precise and restricts the numerator to births of a specified order, say order i ($i = 1,2, 3, \ldots$), and the denominator to women of parity $i-1$ ($i = 1, 2, 3, \ldots$), that is, only those women at risk of a birth of order i. Where age-specific also, this is known as an age-parity specific fertility rate: it is specific both by the age and the parity of the woman. Age-parity specific rates are conditional in the sense that they are conditional on the event not having previously occurred. A type 2 order-specific fertility rate restricts the numerator to births of order i, but includes women of all parities in the denominator. For an age group, this gives the order-specific fertility rate for the particular age. To illustrate, suppose we have 1000 women aged 25–29 years in a particular year, 500 of whom are of parity 0 (childless) and 500 of parity 1 and above (women who are already mothers), and that 50 first births occur to these women during the year. The age-parity specific first birth rate at age 25–29 years is 50/500*1000 or 100 first births per 1000 childless women aged 25–29 years, per annum – a type 1 rate. The age-order specific first birth rate at age 25–29 years is 50/1000*1000 or 50 first births per 1000 women aged 25–29 years, per annum – a type 2 rate.

Both order-specific and parity-specific rates may also be specific by duration since marriage or start of union, or since some other event such as a previous birth (for second and higher order births), or since leaving education, or after arrival in a country of destination. A duration scale can either replace, or be combined with, age. Fertility rates specific by order of birth based on vital registration data will be inaccurate wherever, as sometimes occurs, the order of birth as recorded in a particular system is not based on the woman's complete birth history; population registers or survey retrospective fertility histories are an alternative source.

Fertility rates may vary by parity, and in modern contracepting populations always do so. Because any given overall level of fertility may be reached through differing patterns of parity-specific fertility, measures known as parity progression ratios (PPRs) were developed in the early 1950s. They represent the probability of making each transition in the family building process. The PPR of order i, a_i, is defined as the probability of proceeding from parity i to parity $i+1$. It can be obtained as the proportion of women of final parity i and above, who, by the end of childbearing, have had at least $i+1$ births. Here $i = 0, 1, 2 \ldots m-1$, where m is the maximum number of births to any woman in the population. These ratios express, in other words, the probability that a woman who has had a given number of live births, will have at least one further birth. In their original form, PPRs are calculated on a cohort basis but they are meaningful for any group of women aged 45 years plus. Methods for estimating these for women who have not reached the end of childbearing have also been proposed (Brass and Juarez, 1983).

Timing of Fertility

The principal measures of fertility timing are set out in Table 2. They are somewhat less numerous than indicators of fertility level. The mean and median age at birth are the most basic factors. Somewhat more precise is the mean or median age-specific by order of birth; mean or median age at first birth; at second birth; and so on. Mean and median ages may be obtained from either period or cohort data, and as with measures of the level of fertility, time series of these will generally differ. Whether or not specific by order, the period mean or median age at birth can be calculated in crude or standardized form, and published sources do not always indicate which of these is presented. The period crude mean age at birth (or at first birth, second birth, etc.) is obtained simply as the arithmetic mean age of all women having a (first, second, etc.) birth in a given period. The crude mean age at birth is widely used but has the disadvantage, in

Table 2 Selected measures of fertility timing

Measure and time reference[a]	*Definition*[b]	*Notes*[c]
Mean age at birth (crude) Period; cohort	$\dfrac{\sum_{15}^{49} xW_x^b}{\sum W_x^b} + 0.5$	W_x^b = the number of women aged x last birthday having a birth Where age is grouped, x = mid-point of each age group
Standardized mean age at birth Period	$\dfrac{\sum_{15}^{49} xF_x}{\sum_{15}^{49} F_x} + 0.5$	Where age is grouped, x = mid-point of each age group
Median age at birth (crude) Period; cohort	Median age of women having a birth in a period or, within a cohort, median age of women at childbirth	
Standardized median age at birth Period	Median of the age-specific fertility distribution	
Mean age at i-th birth (crude) Period; cohort	$\dfrac{\sum_{15}^{49} xW_{x,i}^b}{\sum_{15}^{49} W_{x,i}^b} + 0.5$	W_x^b = women aged x last birthday having a birth of order i Where age is grouped, x = mid-point of each age group
Standardized mean age at i-th birth Period	$\dfrac{\sum_{15}^{49} xF_{x,i}}{\sum_{15}^{49} F_{x,i}} + 0.5$	$F_{x,i}$ = age-order specific birth rate of order i, during a year or period (defined in **Table 1**)
First birth interval		
Cohort; for synthetic period version, see text	Duration from marriage (or start of union) to first birth	Less useful where moderate to high proportions of first births occur outside of a union
Second, third, etc. birth interval Cohort; for synthetic period version, see text	Duration from first to second birth, second to third birth and so on	Caution: Cannot be calculated from the mean ages at births of each order, unless specifically for women with $i+$ births; see text.

[a]All measures given here relate either to a calendar year, time period, or cohort. For clarity, subscripts denoting the time reference are omitted, as most of the measures can be specified in either period or cohort form. In a period index, events relate to those occurring in the year or period, at age x where specified. In the cohort case, events are those occurring to members of the cohort concerned, at age x where specified.
[b]The measures defined in female terms here can be defined analogously for men, but the male versions are rarely used.
[c]Throughout the table, age x denotes age x in completed years or, equivalently, age x at last birthday.

a period context, of being influenced by the age structure of women of childbearing age, which can vary through time and from one country to another. Far better for the purposes of period analysis, although more demanding of data since population denominators are required to calculate age-specific rates, is the standardized mean age at birth, or at first birth, second birth, and so on. Standardization is unnecessary in a cohort framework, which is self-standardizing, although care should be taken in comparisons of cohorts widely differing in mortality during the childbearing years. The standardized mean age at birth is obtained by weighting by the relative period age-specific fertility rates at each age (see Table 2) and so is, in fact, the mean of the age-specific fertility distribution. Similarly, the standardized mean age at *i*-th birth uses as weights, the relative age-order-specific fertility rates (type 2, not type 1 rates). The standardized mean age at birth is not a pure measure of fertility timing since it is influenced not only by timing but also by the overall level of fertility. If populations A and B have identical (standardized) mean ages at each order of birth but if proportionately more women in A than in B have births of higher orders, the standardized mean age at birth will be older in A than in B. The mean age at last birth is occasionally used in historical demographic literature as an indirect indicator of the presence of birth control. It can be calculated, without bias, only for women who have reached the end of reproduction (age 45 or 50 years).

Fertility tempo is also measured by the mean or median duration of birth intervals. The first birth interval is the time from marriage, or start of informal union, to the first birth. This interval may be of limited utility where a large proportion of births occur outside of formal or informal marital unions. Later intervals are obtained as the duration from first to second birth (second birth interval), from second to third birth (third birth interval), and so on. Some care is needed in measuring such intervals. Mean birth intervals are sometimes estimated erroneously from the ages of women at births of successive orders of birth. This is incorrect because the ages at successively higher orders of birth are based on women of differing ultimate family sizes. The difficulty arises because women who ultimately have larger families are usually younger at births of any given order than are those with smaller completed families. The *i*-th birth interval is calculated instead as (1) the time from birth $i-1$ (or start of union where $i = 1$) to birth i among women with i or more births, or equivalently as (2) the age at birth i minus the age at birth i-1 (or at the start of union when $i = 1$) among women with i or more births. Where individual level data are available, means or medians may then be calculated. The median may be preferred to the mean birth interval, since birth interval distributions are typically positively skewed. Synthetic or hypothetical mean or median birth intervals for time periods may be obtained from the life tables used in constructing PPPRs (see Section Period Parity Progression Ratios below), thus giving a period measure of birth timing analogous to, and supplementing, the standardized mean age at birth (Ní Bhrolcháin, 1987).

The mean length of a generation is of importance in stable population theory. It is defined as the time it takes a stable population to grow by the factor net reproduction rate (NRR). It is represented in stable population theory by the symbol T and is given by $T = (\ln NRR)/r$, where r is the intrinsic growth rate of a stable population (*see* Preston et al., 2001; Population Dynamics: Theory of Stable Populations).

More Complex Indicators

The TFR and Associated Indices

Since a set of specific fertility rates for a period can be numerous, single-figure indices that summarize them are convenient and often a practical necessity. The classic method of condensing them is the synthetic or hypothetical cohort indicator. A period synthetic cohort indicator is obtained in one of two ways: by summing age-specific rates (type 2) across ages, or by combining occurrence-exposure rates (type 1) multiplicatively across ages in a life table calculation. The most widely used synthetic indicator in the fertility arena is the classic period TFR, obtained by adding the age-specific fertility rates of a given year or period across ages 15–49 years. The most familiar example of the multiplicatively produced synthetic indicator is period life expectancy (*see* Demographic Measurement: Nuptiality, Mortality, Migration, and Growth). The TFR is routinely interpreted as representing the mean family size in a hypothetical cohort of women who experienced the age-specific fertility rates of the period in question throughout their childbearing years.

Closely related to the classic TFR are the gross reproduction rate (GRR) and the NRR. The GRR is simply the TFR confined to female births, and can be seen as the average number of daughters a woman would have if she experienced the age-specific female birth rates of a particular period. The NRR is obtained by modifying the GRR to take account of female mortality up to the end of the reproductive age range (see Table 1). It can be interpreted as the average number of daughters who would be born to a newly born cohort of girls in a stable population in which age-specific female fertility and mortality rates remain fixed (see Population Dynamics: Theory of Stable Populations). In a theoretical, stable population, the NRR represents the extent to which generations replace themselves. Under stable conditions, an NRR of <1, 1, or >1 means that successive generations are, respectively, declining, stationary, or growing in numerical size. The GRR is roughly half the size of the TFR. The NRR is less than the GRR, the gap between them depending mainly on the level of female mortality at ages under 50 years: the higher the level of mortality, the greater the disparity between the GRR and the NRR. The TFR, GRR, and NRR can also be specified on a male basis, using male age-specific fertility rates and male survivorship, and the results will in general differ from the female values. Female rates are, however, more widely available and more reliable and are used universally; however, male rates are used when a specific focus is on male fertility or in theoretical work.

Difficulties with the TFR

A key advantage of the TFR is that it is standardized for age and that it is relatively undemanding of data. But it has shortcomings as a measure. A theoretical difficulty with the TFR and with synthetic cohort indicators in general, is that they express period events in terms of lifetime experience. Mean family size is conceptually meaningful for a cohort but the mean family size of a period has no concrete meaning (Ní Bhrolcháin, 1992). The synthetic cohort interpretation can be avoided by thinking of the TFR as a convenient summary of the level of a phenomenon in a particular period. Nevertheless, the difficulty remains that time-trends in fertility are not homogeneous among those at risk, but can vary by parity, by age, and by duration. No single-figure indicator can accurately represent the multiple dimensions of change. Finally, the TFR is highly subject to variations in the timing of childbearing. When the pace of childbearing is accelerating, the period TFR is above the corresponding cohort mean family sizes, and when the pace is decelerating, the period TFR falls below the associated cohort values. The TFR is more volatile than the comparable cohort series for two main reasons: it takes no account of the past fertility experience of the women at risk at a particular time and, relatedly, it is not standardized for the parity distribution of the population at risk. The TFR of a given period is influenced both by the behavioral parameters of the period and by the impact of the fertility of previous years on the distribution of exposure in the period.

One time-honoured solution, due originally to Hajnal (1947), is not to rely exclusively on period analysis to interpret trends but to use cohort fertility in conjunction with period information: cohorts, he suggested, are the best guide to long-run trends and parity-specific period indicators better describe recent and current trends. Further approaches to handling the shortcomings of the classic TFR are described in the two sections that follow.

Period Parity Progression Ratios

The period parity progression approach to fertility measurement is an alternative to the classic TFR, and goes a long way toward addressing the sensitivity of the TFR to changing tempo. The period parity progression ratio (PPPR) is defined for each order of birth. It is a synthetic indicator representing the PPR that would result if a cohort were to experience during their lifetime the parity-specific, duration-specific, and/or age-specific birth probabilities of a particular period. An indirect method of estimating these is due originally to Henry (1953, translated 1980) and a direct method to Ní Bhrolcháin (1987). The PPPR is calculated by cumulating parity specific rates (type 1) multiplicatively, in life table format, for each order of birth. The parity specific rates may be specific by duration, by age for first birth and duration for later births, by age alone, or by both age and duration (Ní Bhrolcháin, 1987; Murphy and Berrington, 1993; Rallu and Toulemon, 1994). PPPRs largely correct for differences in composition resulting from past experience and have the advantage also that they do not produce results that would be impossible in a true cohort. The PPPR approach improves on the classic TFR not only in standardizing for parity and in removing tempo effects, but also in measuring multiple facets of the fertility of a given period, and in providing multiple indicators of time-trends.

The PPPRs can be used to obtain an estimate of the period TFR that is alternative to the standard TFR, generated as

$$\mathrm{TFR(PPPR)} = a^p_{0,t} + a^p_{0,t} \times a^p_{1,t} + a^p_{0,t} \times a^p_{1,t} \times a^p_{2,t} + \cdots + a^p_{0,t} \times a^p_{1,t} \times a^p_{2,t} \times \cdots a^p_{m-1,t}$$

where $a^p_{i,t}$ is the PPPR of order i for period t, and m is the maximum number of births occurring. The TFR (PPPR) has the advantage over the conventional TFR that it is standardized for parity and also removes much of the timing influence to which the classic TFR is subject. Like the classic TFR, however, it is a one-dimensional measure.

Tempo Adjustment

The decades since the 1970s in developed countries have been marked by very substantial shifts to later ages at childbearing. The result is a sizable downswing in the TFR that has made it even less trustworthy than usual as a guide to longer-run fertility levels. And while the period parity progression approach provides a useful counterweight to tempo shifts, it is fairly demanding of data, requiring parity specific rates by age and/or duration. One methodological response is to attempt to remove the influence of tempo change from the TFR and so produce a tempo adjusted TFR, denoted as TFR* (Bongaarts and Feeney, 1998). The approach has been much discussed, and has been developed further in a number of directions (Kohler and Philipov, 2001; Kohler and Ortega, 2002; Ediev, 2008). Demographic opinion remains divided on the case for and utility of tempo adjustment. Difficulties with tempo adjustment include lack of parity specificity of the TFR*, erratic behavior of TFR* under realistic theoretical scenarios of change, lack of evidence validating tempo adjusted measures as estimators of underlying cohort values, and that the tempo component is integral to period fertility measures where the aim is to explain either period change or cross-national differences (Lesthaeghe and Willems, 1999; Van Imhoff and Keilman, 2000; Schoen, 2004; Ní Bhrolcháin, 2011). If the objective is to seek accurate and efficient estimators of the final fertility of cohorts that have not yet completed their childbearing, relying on tempo adjustment alone is limiting. Recent approaches move away from using tempo adjustment to characterize a particular period's fertility, and instead adopt a broader framework aiming explicitly to estimate the completed fertility of cohorts (Cheng and Lin, 2011; Cheng and Goldstein, 2012). This alternative strategy appears to be promising.

See also: Demographic Techniques: Data Adjustment and Correction; Demographic Techniques: Indirect Estimation; Life Table; Period and Cohort Analysis in Demography; Population Dynamics: Theory of Stable Populations.

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